imitation milk
and imitation milk products

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - ROME

IMITATION MILK AND IMITATION MILK PRODUCTS

FAO, 1974

CORRIGENDA

Page			
vii, line 2		Replace	"developed" with "developing"
1, line 6			"source" with "sources"
4, line 3			"products of" with "products or"
5, line 39			"other than filled milk" with "(other than "filled milk")"
20, heading of Table 10			"ML" with "ml"
21, heading of Table 11			"ML" with "ml"
30, heading of Table 17			"DEVELOPED" with "DEVELOPING"
34, line 33			"toppings)" with "toppings (89))".
39, line 1			"At present, liquid" with "At present liquid"
39, line 11			"feedstaff" with "feedstuff"
43, footnote, lines 3 and 4			"3.9 - 32.6 Pf/kg" with "4.8 - 32 Pf/kg"
line 5			"DM 0.39 - 0.68 or US$ 0.15 - 0.27" with "DM 0.40 - 0.67 or US$ 0.16 - 0.26"
48, line 35			"90 percent" with "60 percent"
66, heading of Table 33		Delete	"COPRA"
69, line 20		Replace	"lysine methionine" with "lysine, methionine"

Latest information

The new title of the Protein Advisory Group (PAG) is "Protein-Calorie Advisory Group of the United Nations System" (see PAG Bulletin, Vol.IV, No. 3, September 1974).

The international market prices of selected oilseed meals and oils as at 3 October 1974 (acc. to Oil World Weekly of 4/10/1974, see also Tables 33 and 35, respectively) in US$/metric ton were:

Oilseed meals	Soybean	Groundnut	Cotton	Rapeseed	Sunflower	Fish
(see Table 33)	230	188	190	131	166	298

Oils	Soybean	Cotton	Groundnut	Coconut	Sunflower	Fish
(see Table 35)	1 184	1 200	1 161	935	1 220	590

As compared with the prices in March 1974, prices for soybean, groundnut, cottonseed and sunflower seed meal increased whereas the prices for rapeseed and fish meal fell. The prices for soybean, cottonseed and sunflower oil increased sharply, those for groundnut and fish oil moderately. The price for coconut oil decreased by more than 25 percent as compared with the price in March 1974.

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IMITATION MILK AND IMITATION MILK PRODUCTS

(Milk-like Products)

With particular reference to existing and potential protein raw material for the manufacture of imitation milks and imitation milk products

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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FOREWORD

Growing demand and rising prices for milk products, rapid development of the food industry supported by immense research activities in food technology and engineering and the growing awareness of governments for the potential and food value of oilseeds for human consumption comprise some of the major factors which led and lead to the manufacture of imitation milk products.

As Director of the Animal Production and Health Division of FAO, I take great interest in the types of imitation milk (and meat) products marketed, their composition and technology, and the role such products may play in the future, especially in regard to the supply of protein raw material for their manufacture, the bulk of which is presently used for animal feeding.

Hence, two of my staff members were requested to prepare desk studies on artificial milk and artificial meat, respectively. Dr. Fritz Winkelmann undertook to prepare the desk study on artificial milk which has resulted in this publication.

Taking into account the growth of the world population, the uncertainty of the outlook for world food supplies and therefore the danger of a world food shortage which is likely to hit first and most seriously the low income groups of countries with an unsatisfactory food and nutrition situation, all efforts must be welcome which aim at improving the availability of nutritious and wholesome food. This is perhaps the most important reason why we in FAO regard imitation milk products as a challenge rather than as a menace for a dairy industry, a complement rather than a substitute.

We would like to see the different types of imitation milk of as high nutritive value and as palatable as possible. But at the same time we wish to see them cheap, so they are available for poor people in the world. Challenged by such development, the dairy production of the world should concentrate on higher and cheaper production.

As Dr. Winkelmann has pointed out in his conclusions, the dairy industry has a very important role to play in the economic development of many developing countries as a supplier of a food of high biological value and as a supplier of work as a labour-intensive branch of agriculture. I also agree with his view that research efforts should be intensified which aim at improving our knowledge about the functional characteristics of milk constituents in order to pave the way for their increased use in and with other foods, for instance to upgrade their nutritional value and improve their taste, flavour, etc., in addition to the traditional uses of milk. But I want to add that more research is also needed in order to reduce milk production costs in difficult ecological climatic conditions which prevail in the developing countries. While it cannot be the purpose of a foreword to produce a whole list of research priorities in the field of dairy technology and husbandry, it should be stressed that the dairy industry should increase their contribution to the world food supply both as regards quantity and quality using research as a tool to comply with this aim. Nature has produced milk, an excellent food, science and modern technology have made it possible to use milk in various forms far from its source of production both as regards time and distance. The answer of the dairy industry to the challenge of imitation products should be to use science and modern technology to make milk, milk products and combinations of milk and milk constituents with other foods available to an increasing percentage of the ever-expanding world population.

H.A. Jasiorowski
Director,
Animal Production and Health Division, FAO

FOREWORD

Growing demand and rising prices for milk products, rapid development of the food industry supported by immense research activities in food technology and engineering and the growing awareness of governments for the potential and importance of substitutes for human consumption are some of the major factors which have led to the manufacture of imitation milk products.

As Director of the Animal Production and Health Division of FAO, I take great interest in the types of imitation milk (and meat) products marketed, their composition and technology, and the role such products may play in the future, especially in regard to the supply of protein raw material for their manufacture, the bulk of which is presently used for animal feeding.

Hence, two of my staff members were commissioned to prepare desk studies on artificial milk and artificial meat, respectively. Dr. Fritz Winkelmann undertook to prepare the desk study on artificial milk which was compiled in this publication.

Taking into account the growth of the world population, the uncertainty of the outlook for world food supplies and therefore the danger of a world food shortage which is likely to hit first and most seriously the low income groups of countries with an unsatisfactory food and nutrition situation, all efforts must be welcome which aim at improving the availability of nutritious and wholesome food. This is perhaps the most important reason why we in FAO regard imitation milk products as a challenge rather than as a competitor to the dairy industry, a complement rather than a substitute.

We should like to see any imitation milk of as high nutritive value and as palatable as possible. But at the same time we wish to see them cheap, so they are available for poor people in the world. Challenged by such development, the dairy production of the world should concentrate on higher and cheaper production.

As Dr. Winkelmann has pointed out in his conclusions, the dairy industry has a very important role to play in the economic development of many developing countries as a supplier of a food of high biological value and as a supplier of work as a labour-intensive branch of agriculture. I also agree with his view that research efforts should be intensified which aim at improving our knowledge about the functional characteristics of milk constituents in order to pave the way for their increased use in and with other foods, for instance to upgrade their nutritional value and improve their taste, texture, etc., in addition to the traditional uses of milk. But I want to add that more research is also needed in order to reduce milk production costs in difficult ecological climatic conditions which prevail in the developing countries. While it cannot be the purpose of a foreword to produce a whole list of research priorities in the field of dairy technology and husbandry, it should be stressed that the dairy industry should increase their contribution to world food supplies and improve protein quality using research as a tool to comply with this aim. Nature has provided milk, an excellent food, science and modern technology have made it possible to use milk in various forms for some time now, often [illegible]. This should be the challenge of the dairy industry. The challenge of imitation products should be to use science and modern technology to make milk, milk products and combinations of milk constituents with other foods available to an increasing percentage of the ever-expanding world population.

[illegible]
Director
Animal Production and Health Division, FAO

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1. INTRODUCTION

The purpose of the forerunner of this publication, the "Draft Desk Study on Artificial Milk, May 1973" was to inform the members of the Animal Production and Health Division of FAO, including the field experts, about the production of artificial milks for human consumption, the substitution effect these products might have in the future and the potential protein sources (especially those derived from source other than milk) for these products.

However, the Draft Desk Study met with such widespread interest, including people outside the dairy industry, that it was decided to give the publication a wider distribution. In re-writing the draft study, the author has introduced changes which were considered necessary for a publication with a wider distribution. The changes comprise mainly the inclusion of a chapter on the nutritive value of milk constituents; up-dating and enlarging the chapter on the composition and manufacture of imitation milks, especially of filled milk, including a sub-chapter on infant formulae; and up-dating and expanding the chapters on whey protein, leaf protein and single-cell protein.

In a publication covering such a wide field the author has had to be selective with regard to the topics to be included; the examples given of technological processes in trial and commercial stages, and the literature referred to and quoted. In view of the need for adequate protein supply in many developing countries, special attention was paid to the statements and reports of the FAO/WHO/UNICEF Protein Advisory Group (PAG).

In principle, the chapters dealing with matters covered by recent FAO publications have been kept short and anyone who has a particular interest in the topics concerned will find more detailed information and bibliographic references in these publications. The publications include:

- in the <u>field of milk product standards</u> and of <u>food standards in general</u>:

  - Code of Principles concerning Milk and Milk Products, International Standards and Standard Methods of Sampling and Analysis for Milk Products, 1973, Seventh Edition; CAC/M 1-1973;

  - Recommended International General Standard for the Labelling of Prepackaged Foods, 1969; CAC/RS 1-1969;

  - Recommended International Code of Practice, General Principles of Food Hygiene, 1969; CAC/RCP 1-1969;

  - Codex Alimentarius Commission, Procedural Manual, 1973, Third Edition; CX 8/7;

- in the <u>field of nutrition</u>:

  - Kon, S.K. (1972) Milk and Milk Products in Human Nutrition, Second Edition; FAO Nutritional Studies No. 27;

  - Energy and Protein Requirements; Report of a Joint FAO/WHO <u>ad hoc</u> Expert Committee, 1973; FAO Nutrition Meetings Report Series No. 52 and WHO Technical Report Series No. 522;

- Amino-Acid Content of Foods and Biological data on Proteins; FAO Nutritional Studies No. 24, 1970;

- in the field of edible protein products from oilseeds:

  - Technology of Production of Edible Flours and Protein Products from Soybean; Agricultural Services Bulletin No. 11; AGS:ASB/11 (1971);

  - Technology of Production of Edible Flours and Protein Products from Groundnuts; Agricultural Services Bulletin No. 10; AGS:ASB/10 (1971);

  - Technology of the Production of Cottonseed Flour for Use in Protein Foods; Agricultural Services Bulletin No. 7; AGS:ASB/7 (1971).

These publications include lists of equipment manufacturers.

FAO is prepared to advise and assist countries in the establishment of industries to manufacture products such as protein concentrates and isolates which can be used as extenders of milk and as substitutes for milk products.

- in the field of economics:

  - FAO Commodity Review and Outlook (CCP document series);

  - Agricultural Commodity Projections 1970-80, 1971, CCP 71/20;

  - Documents of the Intergovernmental Group on Oilseeds, Oils and Fats (CCP:OF document series);

  - National Dairy Policy Reviews (CCP document series);

  - International Dairy Situation and Outlook (prepared twice per year for the Industry Cooperative Programme).

The publication is intended for government officials in developing countries who have to deal with dairy (and food) industry development; for students of FAO regional and inter-regional dairy training courses and students of other dairy training courses; for people working in or for the dairy industry and other branches of the food industry who are interested in the developments taking place in the food industry in general and in the dairy industry in particular. It is not intended for scientists working in specialized fields of human nutrition, food technology, food chemistry, food legislation, plant breeding, etc.

The title of the publication has been subject to a great deal of discussion and exchange of views with the authorities concerned on the subject. The decision to use the title "Imitation Milks" (instead of the former title "Artificial Milks") was based mainly on the following considerations: there is no internationally agreed definition for "artificial milk", nor is there one for "synthetic milk", "vegetable milk", "manufactured milk", "substitute milk", "milk replacer", etc. whereas the term "imitation milk" has been defined by an FAO/WHO Committee of Government Experts, within the framework of a Code of Principles concerning Milk and Milk Products, which has been accepted by 71 countries. It is stressed that the Code does not prescribe the use of the term "imitation" as part of the designation of imitation milk and imitation milk products except in the case of label designations or presentation of products in a manner which is likely to lead the purchaser to suppose that they are milk or milk products.

2. DEFINITIONS

At the international level FAO has provided a forum to enable world-wide agreement to be reached on the terminology applicable to milk[1] and milk products and their imitations, by establishing a Committee of "Government Experts on the Use of Designations, Definitions and Standards for Milk and Milk Products" which has now become a subsidiary body of the Codex Alimentarius Commission ("FAO/WHO Committee of Government Experts on the Code of Principles concerning Milk and Milk Products").

The work commenced in 1958 when the Committee of Government Experts at their first session agreed on a preliminary text of a "Code of Principles concerning Milk and Milk Products", based on a draft prepared by the International Dairy Federation (IDF) (51, 52, 193, 194, 195).

The Code of Principles aims at consumer protection and fair practice in the trade of milk and milk products, mainly by ensuring the precise use of the term "milk" and the terms used for different milk products, by avoiding confusion arising from the mixing of milk and/or milk products with non-milk fats and/or non-milk proteins and by prohibiting the use of misleading names and information for products which are not milk or milk products.

This Code has been accepted by 71 countries either in full or in part or for implementation within a given period of time. In this context it should be noted that the Code was not given the status of an international convention, such as the Stresa Convention on Cheese, with its full diplomatic procedure, but comprises a number of recommended rules "set out in such a manner that they can be accepted by governments so wishing without recourse to Treaty Procedure" (36).

The complete text of the Code of Principles is contained in Appendix 1, together with the Committee's explanatory Notes and Decisions concerning Declarations of Acceptance by the Governments of Austria, New Zealand, the United Kingdom and the United States of America. Designations for milk, milk products and composite products are covered by Articles 1, 2 and 3 of the Code. The most important feature of the definitions given for these products is that prohibiting the replacement of any milk constituent. Article 4 covering "other products" deals especially with imitation milk and imitation milk products.

The Code of Principles

(i) defines imitation milk and imitation milk products as commodities which are likely to lead the purchaser and/or consumer to suppose that they are milk, milk products or composite products as referred to in Articles 1, 2 and 3 of the Code, but in which a milk constituent has been replaced, and

(ii) prohibits these products to be labelled and/or presented in a manner which is likely to lead the purchaser and/or consumer to suppose that the products are commodities as referred to in Articles 1, 2 and 3 of the Code, with the proviso that the purchaser and/or consumer is adequately informed if such products are either designated by the name of the product referred to in Articles 1, 2 and 3, preceded by the word "imitation" or by a distinct name and/or description indicating the true nature of the principal raw materials used.

The Government Experts were of the opinion that, whilst margarine is correctly designated by the term "margarine", the designations "filled milk", "filled cheeses", etc. were misleading within the meaning of Article 4. Their use was, therefore, incompatible with the Code. (See also below).

1/ The term "milk" refers to cow's milk unless otherwise stated. See also Article 1 of the Code of Principles (Appendix 1 of this publication).

To avoid any misunderstanding, it should be noted that the Articles of the Code do not contain any provision precluding the exchange of milk constituents with similar products of the manufacture of substitute products, nor does the Code prescribe that the world "imitation" be used, unless the names of products are employed which are covered by Articles 1, 2 and 3 of the Code.

The use of milk substitutes for human consumption is, however, prohibited by national legislation in several countries (2). In addition to the term "imitation milk" there are other terms in use to designate such products.

In an international survey carried out in 1969/70 by the International Dairy Federation on "Imitation and Synthetic Milk and Dairy Products" the following terms and definitions appear:

> "Imitation products - which contain at least one major milk constituent, usually skim milk or skim milk powder and where vegetable fat replaces butterfat. What have been termed 'filled milk' products are included under this definition".
>
> "Synthetic products - which contain no dairy product although some include sodium caseinate as an ingredient" (104, 105, 106, 109).

R. Waite,[1/] of the Hannah Dairy Research Institute, Ayr, (United Kingdom) (187) in a paper entitled "Artificial Milk" uses the terms "filled milk", "imitation milk" and "synthetic milk" which he defines as follows:

> "Filled milk is a product made by combining fats or oils other than milk fat with milk solids. The milk solids may be in the form of skimmed, evaporated or condensed milk or skimmed milk powder.
>
> Imitation milk, on the other hand, is material which purports to be or resembles milk but contains none of the milk products just mentioned or, of course, milk fat. It is argued that the sodium caseinate often used in imitation milk is a chemical and not a milk solid, that is, it is a product resulting from a chemical reaction in which calcium is replaced by sodium.
>
> Synthetic milk is a term which occurs less frequently in the literature and has been defined as a product manufactured by chemical means. At first sight it appears to be almost synonymous with imitation milk, but one tends to find the term used more in medical literature where it denotes material to which great care has been given to ensure an excellent nutritive value and which is often used in the feeding of very new babies."

O. Ballarin (10) a member of the FAO/WHO/UNICEF Protein Advisory Group (PAG) defined "substitute milks" as "products which are physico-chemically and organoleptically similar to milk, having approximately the same percentage of fat, proteins, carbohydrates and salts as cow's milk, some of these substances may or may not originally come from cow's milk." He made the following distinctions between the milk substitutes - "filled milk", "imitation milk" and "vegetable milk":

"filled milk" (or "semi-synthetic milk")	-	an emulsion of vegetable fat in skimmed milk.
"imitation milk" (or "synthetic or artificial milk")	-	an emulsion of vegetable fat in a colloidal and true solution of calcium caseinate and some non-lactic solids.
"vegetable milk"	-	"milk" obtained from purely vegetable sources: oilseeds, nuts, etc.; with no constituent from cow's milk or broadly from any animal origin.

1/ In a more recent publication Waite uses the term "manufactured milk" (188).

H.H. Moede, U.S. Department of Agriculture, in a paper entitled "Marketing Margins for Selected Dairy Products and their Substitutes" (142) distinguishes between the general types of "substitutes for fluid dairy products" (i) those using one or more components of milk as ingredients, and (ii) those without any milk components (including, however, sodium caseinate).

From the point of view of the dairy industry, it might be worthwhile to consider making a distinction between "dairy" and "non-dairy" imitation products, the former containing at least one major milk constituent such as skim milk or caseinate and the latter no milk constituent at all.

In the United States of America where most of the literature on imitation milk has been published, the term "filled milk" is defined by a specific congressional act, the Filled Milk Act (181) (as is "filled cheese" by the Filled Cheese Act (182)). The term filled milk means:

> "any milk, cream, or skimmed milk, whether or not condensed, evaporated, concentrated, powdered, dried, or dessicated, to which has been added, or which has been blended or compounded with, any fat or oil other than milk fat, so that the resulting product is in imitation or semblance of milk, cream, or skimmed milk, whether or not condensed, evaporated, concentrated, powdered, dried, or dessicated. This definition shall not include any distinctive proprietary food compound not readily mistaken in taste for milk or cream or for evaporated, condensed, or powdered milk, or cream:
>
> Provided that such compound: (1) is prepared and designed for feeding infants and young children and customarily used on the order of a physician; (2) is packed in individual cans containing not more than sixteen and one-half ounces and bearing a label in bold type that the content is to be used only for said purpose; (3) is shipped in interstate or foreign commerce exclusively to physicians, wholesale and retail druggists, orphan asylums, child-welfare associations, hospitals, and similar institutions and generally disposed of by them."

According to the Code of Principles, "filled milk" would be an imitation milk.

Many state laws in the U.S.A. include a similar provision, namely that a food is deemed to be misbranded if it is an imitation of another food, unless its label bears the word "imitation" and immediately thereafter the name of the food imitated. Some of the states in which the sale of filled milk is not illegal require that "filled milk products" be labelled as "imitation milk", "imitation cream", etc. According to R.W. Weik the same applies to products which purport to be or resemble milk, but which do not violate the Filled Milk Act since they contain no milk, cream or any dairy ingredient specified in the Filled Milk Act (190). (Caseinates, which are milk products according to the Code of Principles, were not mentioned amongst the ingredients listed for "filled milk" and can, therefore, be used in the U.S.A. in imitation milks other than "filled milk" shipped in interstate commerce).

However, in November 1972, the Filled Milk Act was declared unconstitutional by the United States District Court for the Southern District of Illinois. It was officially abandoned with the announcement of the Food and Drug Administration (FDA) dated August 1973 that it will no longer be enforced and that filled products may move in interstate commerce. The only remaining restrictions on the sale and movement of these products are those imposed by a number of states. The FDA has proposed that filled milk products which are nutritionally equivalent to the product they resemble should be labelled "filled" followed by the name of the product and that nutritionally inferior filled products intended as a substitute for the milk or milk product concerned be labelled "imitation". Nutritional equivalents have also been detailed (66).

The FDA has invited comments on the suitability and meaning of the word "filled". Suggestions were invited on alternative words or phrases which would be more meaningful and not deceptive or misleading. It should be mentioned here that Decision No. 4 of

the Decisions of the above mentioned FAO/WHO Committee of Government Experts on the Code of Principles recommended that "the Government of the United States give its active attention to the possibility of bringing its Federal and State legislation into line with the Code on the point", i.e. to abandon the term "filled".

The sources of information used for the chapters on composition and production, prices of and trade in imitation milk and imitation milk products do not distinguish between products made with vegetable protein and those made with caseinates. That is why in those chapters the following terminology is used for imitation milks and imitation milk products:

"Filled" milk and "filled" milk products

Imitation milk and milk products in which part or all the milkfat is replaced by vegetable fat.

Non-dairy imitation or "synthetic" milks and non-dairy imitation or "synthetic" milk products

Products resembling milk or milk products which contain no milk product or milk derivate except caseinates.

Otherwise, the terms "imitation milk" and "imitation milk products" as given in the Code of Principles are used.

PAG statement on milk and milk product imitations

As regards nutritional aspects of milk and milk product imitations, the Code of Principles does not suggest that the term "imitation" be reserved for products which are nutritionally equivalent to the products they imitate (see Article 4.1).

The necessity for such products to be "not nutritionally inferior to milk or corresponding milk products" has been stressed by the FAO/WHO/UNICEF Protein Advisory Group at its 16th meeting in Geneva, Switzerland, 8-11 September 1969. and its 17th meeting in New York, U.S.A., 25-28 May 1970, by adopting the following statement (No. 6) which applies to those products which the consumer may assume to be milk or equivalent to milk. It does not apply to other protein-rich foods or beverages (57).

> "The PAG believes that certain protein concentrates, isolates and extracts, nutritionally suitable oils, and acceptable carbohydrates are useful in proper combination as major ingredients of milk substitutes or beverage powders and tinned animal milks, where the resulting products are not nutritionally inferior to milk or corresponding milk products. Whereas PAG favours efforts to stimulate milk production in protein-deficient areas, in those situations where animal milk is not available or is too costly, the production and use of any clearly labelled nutritious milk substitutes or toned milk product as a protein source should be encouraged.
>
> Research and development aimed at improving the quality and lowering the cost of such products should be intensified".

3. THE NUTRITIVE VALUE OF COW'S MILK CONSTITUENTS

Before dealing with the ingredients and composition of imitation milk and imitation milk products some remarks might be useful concerning the nutritive value of the most important milk constituents and their contribution to the human diet. W.M. Ashton (8) states that "as the first food of young mammals it is not surprising that milk has been called the 'perfect food'" and "It is perhaps more correct to regard milk of a given species as being perfectly designed for the suckling young of that species, although with some reservations. For example, the milk of several species is not a good source of iron and copper, but reserves in the liver (and blood) of young mammals usually compensate for this deficiency".

Milk is a good source of easily digestible good quality <u>protein</u>. Cow's milk protein is only surpassed by human milk protein and egg protein in fulfilling the bodily needs for essential amino acids (159) (see also Chapter 5.2, subheading Nutritional Aspects - essential amino acid composition of selected proteins).

Milk is also an important source of <u>minerals</u>, especially calcium and phosphorus, which are necessary for bone-building. Milk also provides other major mineral elements such as sodium and potassium, and essential trace elements including cobalt, magnesium, molybdenum and zinc (94).

Milk contains both the fat-soluble and water-soluble <u>vitamins</u> essential for healthy life and growth (87). Milk fat contains vitamin A, and its precursor carotene in varying amounts depending on the supply of green fodder available to milch cattle, and the vitamins D, E (tocopherols) and K. Milk contributes only a negligible amount of vitamins D and K,and small amounts of vitamin E to the human diet, but a very substantial amount of vitamin A. In some countries vitamins A and D are added to dried skim milk and vitamin D to evaporated milk (24).

Milk is a very good source of the water-soluble vitamins riboflavin (B_2) and cyanocobalamin (B_{12}) and is a fairly good source of thiamine (B_1), pyridoxine (B_6), biotin and choline. The deficiency of milk in nicotinic acid is probably of little consequence because milk is an excellent source of tryptophan (about 500 mg/l) which can be used for the synthesis of nicotinic acid in the body. Folic acid content of milk is reported to be low. Freshly drawn milk is a fairly good source of vitamin C. However, this is oxidized on exposure of milk to light, and in the dark in the presence of metals, particularly copper. Subsequent heat treatment destroys the compound. Milk, other than milk fresh from the udder, is therefore considered as a rather poor source of vitamin C.

<u>Milkfat</u>, like all fats, is of high caloric value (8). It is in a finely dispersed state in milk and is readily assimilated. The fatty acids in oils and fats which are many in number and structure can be classified as 'saturated' and 'unsaturated' (112). Present nutritional and medical knowledge inclines to the view that about 12 percent of a person's total intake of fatty acids (about 2 percent of the total calorie intake) should be in the poly-unsaturate form (91). Cow's milkfat contains 36 percent of its fatty acids in the unsaturated form but only 3-4 percent as poly-unsaturated and it has been suggested that some vegetable oil rich in poly-unsaturated fatty acids, such as soyabean oil, should be included in the diet (188). It has been suggested that lack of these acids may be one of the causes of eczema in babies receiving cow's milk. The comparatively low content of unsaturated fatty acids in milk fat and their effect in elevating the plasma cholesterol, have been much discussed in relation to cardiovascular disease, but there is insufficient evidence to condemn the consumption of normal amounts of milk fat (147, 149, 201).

"Filled" milks in which the milkfat is replaced by a relatively saturated vegetable fat such as coconut oil that lacks significant amounts of linoleic acid is not nutritionally acceptable for children or adults (189) on fat-modified diets. "Filled" milks should be enriched with vitamins D and A. The coconut oil used in imitation (including "filled") milks contains 92 percent of saturated fatty acids, which account for its good keeping properties, and of the 8 percent of unsaturated fatty acids only 1 percent or less are poly-unsaturated. The PAG has recommended that if coconut oil is used for "filling" skimmed milk, 10 percent of it should be replaced by groundnut oil or some other oil richer in unsaturated fats (161). In the United Kingdom the "Skimmed Milk with Non-Milk Fat Regulations" of 1960 and 1965 prescribe that such products be labelled 'unfit for babies' with the exception of certain proprietary brands. The exempted products have to contain milk protein only and poly-unsaturated fatty acids to the extent of 12 percent of the total fatty acids, the fat, protein and vitamin contents being specified for each product (187). Sweetened condensed skim milk or dried skim milks are also unsuitable as such for feeding babies because fat and fat soluble vitamins have been removed (20).

Lactose, like milkfat, a contributor to the energy value of milk, is hydrolyzed in the intestine by lactase, producing glucose and galactose. With regard to a number of reports which have appeared on lactase deficiency in certain ethnic groups, the following excerpt is given from the PAG Statement No. 17 on milk intolerance, issued 2 February 1972 (60).

> "During the last few years, reports have appeared in the world medical literature on the occurrence of low intestinal lactase (exact term: β-galactosidase) activity on large groups of apparently healthy nonwhite populations in different parts of the world. Some of the reports and many articles in the lay press have concluded that milk consumption by these people may lead to untoward reactions in the form of gastrointestinal disturbances ('milk intolerance') and may interfere with the proper utilization of milk nutrients. Doubts have been raised as to whether it is desirable to use milk as a source of supplementary food for children in the developing areas of the world and whether milk and milk products should be exported throughout the world for use in nutrition programmes.
>
> It is the considered view of the PAG, based on the report of its ad hoc Working Group on Milk Intolerance, that the evidence presently available does not justify the above doubts.
>
> Milk is considered a virtually complete food and in the developing areas of the world, where protein deficiency is widespread and protein-calorie malnutrition a serious childhood problem, the use of milk for child feeding programmes is strongly advocated by all nutrition experts. The PAG wishes, however, to emphasize that there are several areas where our knowledge is deficient or lacking on this complex subject and steps should be taken to close the gaps. Physicians in developing countries and authorities supervising milk feeding programmes should also be made aware of current knowledge on this subject and its implications.
>
> It would be highly inappropriate, on the basis of present evidence, to discourage programmes to improve milk supplies and increase milk consumption among children because of the fear of milk intolerance."

Taking into account this statement and summarizing the above short account of the nutritional value of cow's milk, it must be concluded that cow's milk makes an important contribution to the human diet, in particular as regards child feeding.

Table 1 shows that half a litre of average cow's milk per day provides a young child with nearly one-third of the protein required, nearly two-thirds of the calcium, nearly one-third of vitamin A and thiamine, and nearly the whole of the riboflavin (8).

Table 1

APPROXIMATE PERCENTAGE CONTRIBUTION OF 0.5 LITRE OF GOOD QUALITY FRIESIAN MILK TO THE DIETARY ALLOWANCES RECOMMENDED BY THE BRIT. MED. ASSOC. COMMITTEE ON NUTRITION (1950)

Nutrient	2-6 yr. old child		Man (medium work)	
	Recommended daily allowance	% contribution	Recommended daily allowance	% contribution
Calories	1 500 k.cal	20	3 000 k.cal	10
Protein	56.0 g	30	87.0 g	20
Iron	7.5 mg	2	12.0 mg	1
Calcium	1.0 g	60	0.8 g	75
Vitamin A activity	3 000 i.u.(900 μg)	30	5 000 i.u.(1500 μg)	15
Vitamin D	400 i.u.	2	-	-
Thiamine	0.6 mg	35	1.2 mg	20
Nicotinic acid	6.0 mg	7	12.0 mg	3
Riboflavin	0.9 mg	85	1.8 mg	45
Vitamin C	15.0 mg	70	20.0 mg	50
Iodine	0.15 mg	10	0.1 mg	15

Ashton, W.M., 1972, Dairy Industries, 37, 602-611.

Table 2

COMPOSITION 1/ OF WHOLE AND SKIM COW'S MILK, IN LIQUID, CONCENTRATED AND DRIED FORMS, AND LOSSES IN NUTRIENTS IN TREATMENT

	Water	Protein (N x 6.38)	Fat	Carbo-hydrate	Calcium	Vitamin A (retinol) activity		Vitamin D		Thiamine		Riboflavin		Panthotenic acid		Nicotinic acid		Vitamin B_6		Biotin		Vitamin B_{12}		Vitamin C 2/	
						Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)	Amount (ug/ 100 g)	Loss (%)
	. . . . .	Percent	. . . . .																						
WHOLE																									
Raw	87.6	3.3	3.6	4.7	0.12	50	–	2	–	45	–	150	–	350	–	100	–	25	–	1.5	–	0.30	–	2.0	–
HTST treated	87.6	3.3	3.6	4.7	0.12	50	None	2	None	42	<10	150	None	350	?	100	None	25	None	1.5	None	0.30	< 10	1.8	10
Sterilized (in-bottle process)	87.6	3.3	3.6	4.7	0.12	50	None	2	None	30	35	150	None	350	?	100	None	25	3/	1.5	None	Trace	> 90	1.0	50
UHT treated	87.6	3.3	3.6	4.7	0.12	50	None	2	None	42	<10	150	None	350	?	100	None	25	None	1.5	None	0.24	20	1.8	10
Evaporated																									
(1)	68.5	8.4	9.2	12.0	0.30	125	None	5	None	67	40	375	None	875	?	250	?	63	3/	3.4	10	<0.10	90	2.0	60
(2)	73.0	7.0	8.0	10.0	0.26	105	None	4	None	57	40	315	None	735	?	210	?	53	3/	2.8	10	<0.10	90	1.7	60
Sweetened condensed																									
(1)	25.0	8.4	9.2	55.4	0.30	125	None	5	None	103	10	375	None	875	?	250	None	63	None	3.4	10	0.53	30	4.3	15
(2)	29.0	7.3	8.0	53.9	0.27	110	None	4	None	90	10	330	None	775	?	220	None	55	None	3.0	10	0.47	30	3.8	15
Dried																									
Roller	3.0	25.0	27.5	37.5	0.91	383	None	15	None	290	15	1 150	None	2 700	?	760	?	190	None	10.0	10	1.60	30	11.0	30
Spray	3.0	25.0	27.5	37.5	0.91	383	None	15	None	310	10	1 150	None	2 700	?	760	?	190	None	10.0	10	1.60	30	13.0	20
SKIM																									
Raw	90.8	3.4	0.1	4.9	0.12	1	–	0	–	47	–	145	–	360	–	103	–	26	–	1.5	–	0.30	–	2.0	–
Evaporated	80.0	7.4	0.2	10.7	0.26	3	None	0	–	61	40	315	None	780	?	225	?	57	3/	2.9	10	<0.10	90	1.7	60
Sweetened condensed	29.0	9.6	0.3	58.8	0.34	4	None	0	–	120	10	410	None	1 000	?	290	None	73	None	3.8	10	0.60	30	4.8	15
Dried	3.0	36.0	1.0	50.5	1.26	13	None	1	None	450	10	1 530	None	3 800	?	1 100	?	275	None	14.0	10	2.20	30	17.0	20

1/ For simplicity, rounded-off values have been taken for raw milk and all other forms are assumed to have been derived from that particular milk. Two separate values are given for evaporated and for sweetened condensed whole milk to represent two different degrees of concentration current on the international market.

2/ Survival of vitamin C would depend on the amount originally present in the raw milk: 2 mg/100 g is for milk as it leaves the udder.

3/ Appreciable loss of biological availability.

4/ Loss of riboflavin in the fat-globule membrane.

? Indicates possible slight loss.

Kon, S.K., 1972, Milk and Milk Products in Human Nutrition, Second Edition, FAO Nutritional Studies No. 27.

Effect of processing on the vitamin content of milk

In order to prevent milk from spoilage, i.e. to conserve milk nutrients, most liquid milk is pasteurized, sterilized, UHT-treated[1] or boiled before consumption, and large quantities are condensed or dried. The effect of heat treatment on the vitamin content of milk and milk products is presented in Table 2 (115).

Vitamins A and D and the water-soluble vitamins riboflavin, nicotinic acid, pyridoxine and biotin appear to suffer little or no loss in heat processing and recent work shows that there is also only little loss of pantothenic acid occurring. Losses of thiamine and ascorbic acid reach 10 percent in pasteurization and UHT treatment, and 35 percent and 50 percent respectively in in-bottle sterilization. Losses of cyanocobalamin reach 90 percent in in-bottle sterilization and evaporation. Little or no loss of vitamins A, D and E, and of panthotenic acid, nicotinic acid, biotin, thiamine and riboflavin, appears to occur during storage.

However, the 10 percent loss of cyanocobalamin immediately following UHT treatment rose to 20 percent after 14 days and to 60 percent after 180 days, and 20 percent loss of pyridoxine may occur after 14 days and 50 to 60 percent after 180 days. The presence of oxygen during processing and storage and of light greatly increases the losses of cyanocobalamin and of vitamin C as indicated above.

The proximate composition and the mineral content of milk appear to be affected very little by processing to which milk is normally subjected.

While all forms of heat treatment produce some denaturation of the proteins, i.e. the rupture of cross-linkages holding together the polypeptid chains, denaturation of proteins in milk appears to be of little consequence towards its contribution to infants and adult nutrition.

1/ The definition adopted by the International Dairy Federation in September 1973 reads as follows (108):

"UHT milk is a milk which has been subjected to a continuous flow heating process at a high temperature for a short time and which afterwards has been aseptically packaged. The heat treatment must be such that UHT milk shall:

1) conform with the requirements laid down in IDF Standard 48;
2) give turbidity when subjected to the turbidity test (as specified in the IDF Monograph on UHT Milk, 1972, pages 54-55)."

4. IMITATION MILK AND IMITATION MILK PRODUCTS

4.1 Composition and Manufacture [1/]

Ingredients

Fat. The primary vegetable oil used to replace the milk fat in imitation milks and imitation milk products is coconut oil (75). It has been reported that palm oil (17), combinations of soybean and cottonseed oil (20, 141), combinations of corn and sunflower oil (20), and in Chile hydrogenated fish oil are also being used.

Protein. The vegetable proteins used in imitation milks are mainly derived from soya beans. Groundnut protein is also used to a limited extent (see Chapter 5.2).

The only protein of animal origin, other than skim milk, whey protein, casein and caseinates, reported to be used in imitation milk, is fish protein. Pilot scale trials have been carried out in Chile with technical assistance from FAO, and industrial scale production is being implemented (see Chapter 5.1).

Other ingredients used are corn syrup solids, starch, stabilizers, emulsifiers, buffers, sweeteners and artificial colouring agents, and minerals and vitamins (141).

Equipment

Generally speaking, the present-day equipment used in milk plants is also suitable for the manufacture of imitation milk and imitation milk products. A mixing machine for dry ingredients, which is not normally part of the milk plant equipment, would be desirable for the imitation products requiring dry blending of some ingredients (see below).

"Filled" Milks and "Filled" Milk Products

Background. The competitive position of milk fat and vegetable fat is determined by a number of factors, the most important of which are the price of the fats (see also Chapter 5.2), the convenience for consumers of the "filled" products, nutritional aspects (see Chapter 3), and marketing (see also marketing margins as percentage of retail prices given in the price comparisons of Table 14).

The milk product with the highest fat content (besides anhydrous milk fat, butteroil and ghee) is butter, and its substitute, margarine, is according to the IDF "the oldest of the competitors of dairy produce" and one "of the greatest significance" (109). Therefore a few data concerning the development of butter and margarine production at consumption are given to illustrate the trend in 14 important milk-producing countries.

The development of butter and margarine production in ten important milk-producing countries in Western Europe and in Australia, Canada, New Zealand and the United States between 1955 and 1970 (see Table 3) shows that margarine production increased by 23 percent whereas butter production increased only by 15 percent. The share of butter of the total fell from 49.8 percent in 1955 to 48.2 percent in 1970 (107).

1/ In addition to the literature referred to in the text of Chapter 4.1, the following literature has been consulted: 7, 11, 19, 21, 22, 23, 80, 81, 89, 91, 92, 93, 110, 117, 130, 131, 155, 165, 166, 183.

Table 3

DEVELOPMENT OF THE PRODUCTION OF BUTTER AND MARGARINE
IN 14 IMPORTANT MILK-PRODUCING COUNTRIES 1/

1955 = 100	1955	1960	1965	1970
Margarine production	100	114	117	123
Butter production	100	112	119	115
Total	100	113	118	119
Share of total				
Margarine	50.2	50.7	49.6	51.8
Butter	49.8	49.3	50.4	48.2
	100	100	100	100

IDF Document C-DOC 13-1972

Consumption data for the United States show a complete reversal in market preference of margarine and butter: in 1950 per caput consumption of butter was 4.8 kg and margarine 2.7 kg. In 1960, butter consumption dropped to 3.4 kg and continued dropping to a level of 2.3 kg in 1970. Margarine consumption reached 4.3 kg in 1960 and rose to 4.9 kg in 1970 (107). At the same time, more and more milk products in which milk fat was replaced by other fats appeared on the market.

While the replacement of milk fat in other milk products might move at a slow pace in Western Europe where milk and milk products' consumption is traditional, the example of the progress of "filled" milk in the Philippines, where it has approximately 85% of the market, shows that production of "filled" milks is likely to become more and more important, mainly for reasons summarized below (37, 38, 143).

In most countries, the prices of vegetable fats are two to three times lower than milk fat, and this has a direct bearing on the production of products with high fat content, such as whipped toppings, imitation cream, imitation ice-cream and coffee whiteners. Consumer convenience, such as longer-keeping quality of products like whipped toppings and coffee whiteners also plays an important role. Information on the supposed relationship between consumption of animal fats and cardio-vascular diseases is another reason for the progress of "filled" products. Most of these products which have gained a sizeable share of the market in developed countries are produced by big enterprises.

In developing countries which produce vegetable fats and import the greater part of the milk products they consume, substitution of milk fat by vegetable fat is increasing. The reason for filled milk manufacture in Asia generally has been partly economic and partly the desire of the Asian countries to utilize their own raw material, such as coconut, corn or palmoil, to reduce the amount of foreign exchange required for import, and to increase the utilization of their home-grown products.

1/ Australia, Canada, New Zealand, United States, Austria, Belgium, Denmark, Fed. Rep. of Germany, France, Ireland, Netherlands, Norway, Sweden, United Kingdom

It has been reported (143) that since 1971 Thailand, which previously used only milk and milk products, i.e. all its recombined milks utilized butterfat, has now reached the point where approximately 90 percent of the fat content of the milks used is vegetable oil. Some are straight vegetable oils and some are used in conjunction with butterfat.

In Cambodia there are some full milk products on the market and some are a blend of butterfats and vegetable fats.

In Malaysia there has been a tendency to switch to vegetable oil and, although this has been slow, the Government of Malaysia has been urging companies to use home-grown palm oil.

Indonesia at present is using only butterfat in its recombined milk, but it is believed that there are moves afoot to introduce "filled milk" (143).

Most "filled" products are made with coconut oil and skim milk (in liquid or dried form), and a base mix which may contain mono- and diglycerides, sodium caseinate, corn syrup solids, soy protein, carrageenan, starch, artificial colouring and flavouring. Vitamins may also be added.

"Filled" milk. A typical composition of "filled" milk is given in Table 4.

Table 4

TYPICAL COMPOSITION OF "FILLED" MILK

	Whole milk	Filled milk (g/100 g)		
		A	B	C
Fat	3.8	3.8	3.1	3.4
Protein	3.3	4.1	3.3	3.1
Carbohydrates	4.6	5.3	4.9	5.0
Minerals	0.7	0.9	0.8	0.7
Vitamins A & D	+	-	+	-
Riboflavin	+	+	+	+

U.S. Dairy Council Digest, 1968, 39 (2), 7.

This table shows that the chemical composition of "filled" milks is similar to that of whole milk, with the exception, of course, that the fat component is of vegetable origin. Nutrient analyses of four samples of "filled" milks from California, Arizona and Nebraska also showed that the total non-fat solids, calcium and phosphorus contents of the products compared favourably with those in whole milk. Certain of the "filled" milks were higher in essential amino-acids (apparently a reflection of the amount of milk solids not-fat used). The analysis of the total fat and the individual saturated and nine individual unsaturated fatty acids showed that the "filled" milks were very high in lauric acid and very low in linoleic acid when compared with whole milk, which indicated that the type of fat used was coconut oil.

For "filled" milks the equipment required and the manufacturing process is almost identical as for recombined milks 1/. A flow sheet illustrating the manufacture of recombined evaporated milk is given in Figure 1.

Water, heated to a mixing temperature of 40 to 50°C is mixed lump-free with skim milk powder. A measured quantity of fat (butterfat in the case of recombined evaporated milk, or vegetable oils in the case of "filled" evaporated milk), heated to 50°C, is added under constant stirring. The mix is filtered, preheated, de-aerated, heated to 90 to 110°C, cooled to homogenization temperature, homogenized, cooled to 5°C, stored, and filled into cans. The product is sterilized in the cans.

Imitation ice-cream, imitation ice-milk (Mellorine) resemble ice-cream or ice-milk except that milk fat is replaced by vegetable fat. Examples of the composition of mellorines is given in Table 5.

Table 5

COMPOSITION OF MELLORINES

Ingredients	Formulae (%)		
	A	B	C
Water	62.5	62.0	61.1
Milk solids-not-fat	13.0	12.5	11.5
Sugar	14.0	13.0	12.0
Corn syrup solids (42 DE)	6.0	6.0	5.0
Vegetable fat	4.0	6.0	10.0
Stabilizer-emulsifier	0.5	0.5	0.4
Total solids	37.5	38.0	38.9

Hedrick, T.J. Dairy Industries 1969, 34 (3), 127-132.

The stabilizer and emulsifier for A and B may be selected from any suitable compound used for ice-milk, and for C from those suitable for ice-cream.

Imitation sour cream. Examples of the composition of imitation sour creams, dressing bases or dip bases are given in Table 6.

1/ Recombined milk products have been defined by the Joint FAO/WHO Committee of Government Experts on the Code of Principles concerning Milk and Milk Products: "Recombined (product)" is the milk product resulting from the combining of milkfat and milk-solids-non-fat in one or more of their various forms with or without water. This combination must be made so as to re-establish the product's specified fat to solids-non-fat ratio and solids to water ratio (52).

FIG. 1: SIMPLIFIED FLOW DIAGRAM FOR RECOMBINED AND "FILLED" EVAPORATED MILK.

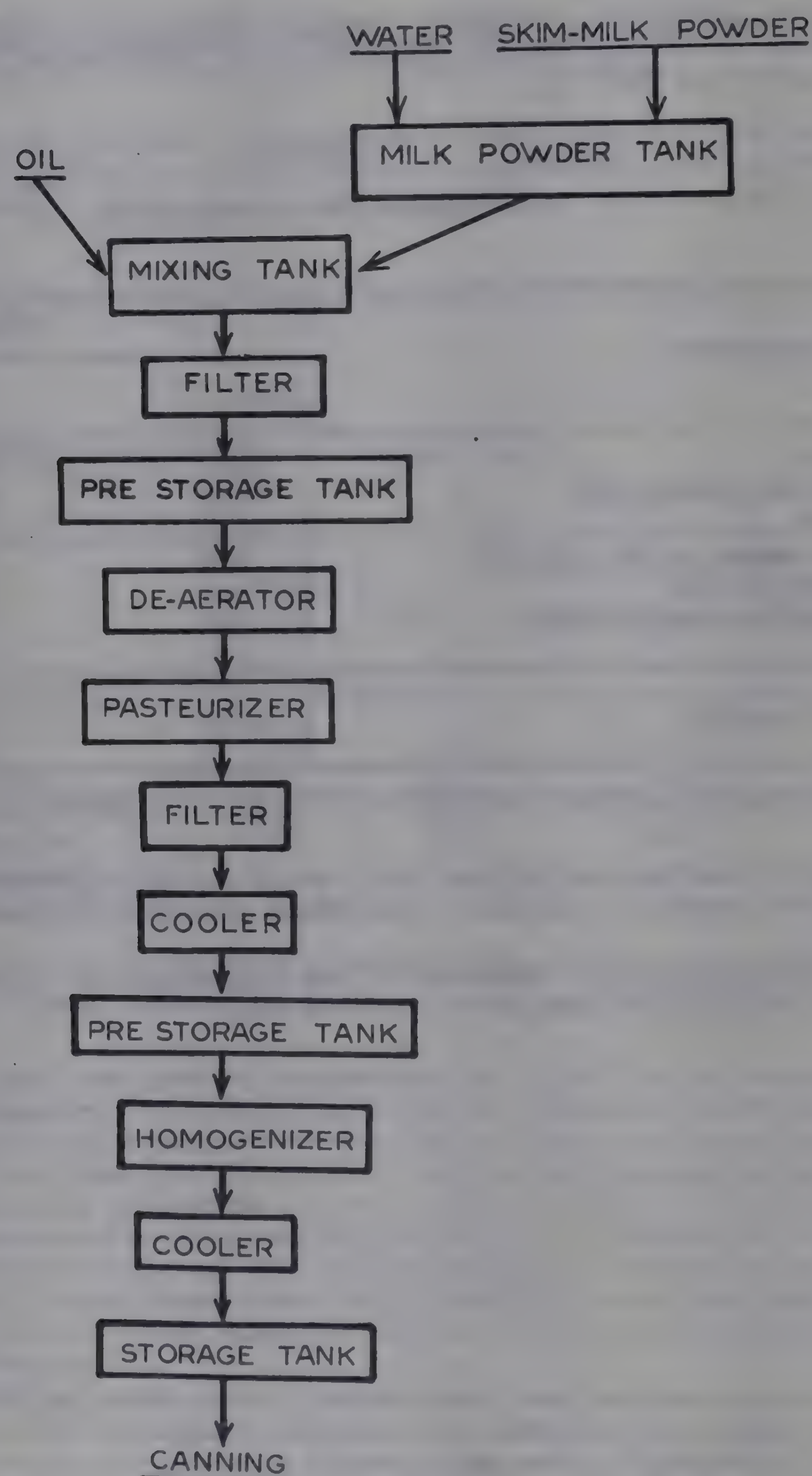


Table 6

COMPOSITION OF IMITATION SOUR CREAMS

Ingredients	Amount (%)	Range (%)
Water	76.2	82.0–64.0
Vegetable fat	14.0	6.0–20.0
Milk solids not-fat	9.0	6.0–15.0
Emulsifier	0.5	0.3–2.0
Stabilizer	0.3	0.1–1.0
Total	100.0	

Hedrick, T.J. Dairy Industries 1969, 34 (3), 127-132.

The emulsifiers and stabilizers mentioned for coffee whiteners (see below), with the addition of tragacanth gum and monocrystalline cellulose as stabilizers, are suitable for these cultured products. Flavourings include onions, chives, blue cheese, salts and spices. The stabilizer, vegetable fat and emulsifiers are added to heated reconstituted or fresh skim milk and thoroughly mixed. After pasteurization, homogenization and cooling, active buttermilk culture is added and the mix is incubated until the pH is approximately 4.5 to 4.6. The product is cooled and packaged in coated cardboard or rigid plastic containers . Other imitation sour creams are prepared by direct addition of lactic or acetic acids to lower the pH to 4.4 to 4.5. The product is immediately packed and allowed to coagulate before cooling.

Non-dairy imitation milk products

Non-dairy imitation milks were frequently reported to have a much lower protein content than whole milk. A typical composition of fluid non-dairy imitation milk is given in Table 7. The sugar, protein, stabilizer and buffer are dry blended and added to the water. The remaining ingredients are added and the mixture is agitated to ensure a uniform consistency. It is then pasteurized, homogenized, cooled, packaged and handled similarly to milk. It is sometimes also sterilized.

Table 7

TYPICAL COMPOSITION OF NON-DAIRY IMITATION MILK (g/100 g MILK)

	A	B	Ingredients
Fat	3.0	3.7	Coconut oil
Protein	1.0	0.9	Soya: caseinate
Carbohydrate	8.0	6.7	Corn syrup: sucrose
Minerals	0.2	0.5	NaCl: $CaHPO_4$
Stabilizer	0.8	+	Carrageen: alginate
Emulsifier	0.4	+	Glycerides
Buffer	0.2	+	Na_2HPO_4
Vitamins A + D	+	+	
Riboflavin	0	0	

U.S. Dairy Council Digest, 1968, 39 (2), 7.

More recent investigations by Kosikowski (118) concerning the nutritive and organoleptic characteristics of thirteen non-dairy imitation milk powders, concentrates and bottled beverages indicated that wide fluctuations existed in riboflavin (1.9 to 418 µg/100 ml), thiamine (0.2 to 54.7 µg/100 ml), protein contents (0.78 to 3.67 percent) and amino-acids such as lysine (4.7 to 13.6 µmole per ml). In all samples, the calcium and magnesium content were significantly lower than in cow's milk reconstituted from whole milk powder, whereas the sodium content was generally much higher, almost threefold in several instances. The appearance of most non-dairy imitation milks closely resembled fresh, pasteurized cow's milk, but the flavour, in the opinion of three milk judges, was not similar and was unaccepable to them. Most imitation milks contained less protein than reconstituted cow's milk, but two contained concentrations of 3.26 and 3.67 percent which is comparable with cow's milk.

Further recent studies (1970-73) by Kosikowski and co-workers in the United States on non-dairy imitation milks (12 powders and 2 concentrates) dealt with their flavour and fat characteristics and their lactic acid fermentation potential (68, 119, 150). Typical flavours of the non-dairy imitation milks, reconstituted to 12 percent dry matter, were flat, foreign and metallic-oxidized or sweet, malty and beany and of reconstituted cow's milk slightly to strongly oxidized (the latter was 12 years' old). The fat content of the imitation powders averaged 26.25 percent; of the two imitation concentrates 7.96 percent; and the three cow's whole milk powders 28.91 percent. The data obtained during 1970-72 (melting points, refractive indices, sterols, fatty acid composition, oxidized fatty acids, acid numbers, peroxide values) showed only one imitation powder containing fat resembling coconut while another apparently contained some butterfat. The majority of the products contained soybean or cottonseed fats or mixed fats, difficult to identify because of hydrogenation. The unsaturated nature of the fatty acids of most of these powders and concentrates suggested that a rapid flavour deterioration can be expected with these products. Oxidized and tallowy flavours were observed, but a number of these non-dairy imitation milk products were relatively stable to changes over 18 to 24 months at 18°C, indicating the presence of inhibitors.

To determine the lactic acid fermentation potential of non-dairy imitation milks containing soy protein or sodium caseinate, Kosikowski and co-workers compared 17 imitation powders and concentrates reconstituted to 12 percent dry matter with reconstituted and fresh cow's milk for their capacity to produce yoghurt, Neufchatel cheese and Cheddar cheese. The reconstituted imitation milks generally displayed a slower acid development and coagulation time in the simulated production of yoghurt and Neufchatel cheese. The products obtained from the imitation milks did not compare favourably in flavour and texture with commercial products made from fresh whole milk. It was not possible to manufacture Cheddar cheese as no curd formation took place after rennet addition to seven reconstituted imitation milks. Kosikowski suggests that, if modifications are made to non-dairy imitation milks, such as adjusting pH and calcium and using sodium caseinate as protein source, it should be possible to form a curd and make acceptable imitations of cheeses such as Mozzarella and Cheddar.

Six individual cultures of lactic acid bacteria grew appreciably more slowly in the reconstituted non-dairy imitation milks than in reconstituted cow's milk.

Imitation Cheddar and blue cheeses in the shape of small cubes have been reported to be produced by extrusion from wheat flour, whey, buttermilk and corn syrup solids with the aid of imitation cheese flavour and other additives (34) (see also Chapter 5.2 soybean protein, textured proteins).

Coffee whiteners. Examples for the composition of coffee whiteners are given in Table 8.

Table 8

COMPOSITION OF COFFEE WHITENERS

Ingredients	Amount (%)	Range (%)
Water	82.25	80.0–85.0
Vegetable fat	10.00	8.0–12.0
Protein	1.00	1.0–3.0
Corn syrup solids	6.00	5.0–10.0
Emulsifiers	0.50	0.2–1.0
Buffer	0.15	0.1–0.5
Stabilizer	0.10	0.02–0.5
Total	100.00	

Hedrick, T.J. Dairy Industries 1969, 34 (3), 127-132.

Common emulsifiers used in coffee whiteners are mono- and diglycerides, polysorbate 60, lecithin, sorbitan tristearate and sorbitan monostearate, which may be used singly or in combination of two or three. Common buffers are sodium hexametaphosphate, disodium phosphate or sodium citrate. They help to compensate for variations in the pH of hot coffee and inhibit feathering. Carrageen is a common stabilizer. A small amount of artificial flavouring may be included.

The protein, sugar, buffer and stabilizer are dry mixed and thoroughly dispersed in water. The mixture is heated; fat, emulsifier and colouring, if desired, are added. The product is then pasteurized, homogenized, cooled and packaged, usually in milk cartons. For distribution it is either held at 4°C or frozen. It is reported that aseptically packaged products are also marketed.

Whipped toppings. Examples for the composition of whipped toppings are given in Table 9.

Table 9

COMPOSITION OF WHIPPED TOPPINGS

Ingredients	Amount (%)	Range (%)
Water	62.7	46.0–75.0
Vegetable fat	25.0	20.0–32.0
Sugar	10.0	6.0–15.0
Sodium caseinate	1.5	1.0–5.0
Emulsifiers	0.6	0.3–1.5
Stabilizer	0.2	0.1–1.5
Total	100.0	

Hedrick, T.J. Dairy Industries 1969, 34 (3), 127-132.

Emulsifiers which may be used in addition to those mentioned for coffee whiteners are propylene glyco monostearate and glycerol lacto palmitate. The manufacturing process is similar to that for coffee whiteners. After homogenization the product should be cooled rapidly and held overnight for improved whippability. The whipped product may be frozen.

Infant Foods

Infant foods destined for feeding babies up to three to four months of age 1/ imitate mother's milk. That is why - strictly speaking - infant foods do not appear to fall within the scope of this publication which deals with imitations of cow's milk and cow's milk products as defined by the Code of Principles. However, imitation milks (liquid, evaporated, condensed, dried) are of special interest because they are used for baby and infant feeding, for which purpose a number of them might not be suitable as already mentioned. Bearing in mind the trend away from breast feeding (62) it is not surprising that producers of vegetable protein products regard the infant food market as very promising. It would appear, however, that the use of cow's milk for infant food will continue to be significant (174).

Table 10 compares some typical values of important constituents of human milk with whole cow's milk: apart from the lower protein and higher carbohydrate contents it should be noted that there is much less calcium and phosphorus in human milk and that the calcium to phosphorus ratio differs from that in cow's milk (29).

Table 10

REPRESENTATIVE SUMMARY VALUES (PER 100 ML)
FOR HUMAN MILK AND COW'S MILK

(Macy, Kelly & Sloan, 1953)

		Human Milk			Mature cows' milk
Stage of lactation		1-5 days	6-10 days	Mature milk	
Energy	kJ	243	310	297	289
Total N	mg	515	317	227	550
Protein N	mg	424	251	188 (=1.2% Protein)	518 (=3.3% Protein)
Casein N	mg	190	110	63	438
Whey N	mg	265	-	95	95
Lactose	g	5.3	6.6	7.0	4.8
Fat	g	2.9	3.6	3.8	3.7
Linoleic acid		6.8 1/	7.1 1/	8.3 1/	1.6 1/
Ca	mg	31	34	33	125
P	mg	14	17	15	96
Fe	mg	0.09	0.04	0.15	0.10
Cu	mg	0.05	0.05	0.04	0.03
Water	ml	87.2	86.4	87.6	87.4

1/ g/100 g milk fat.

Cuthbertson, W.F.J. Glaxo Research Ltd., 1973, Infant Food Formulations, paper presented at the Symposium "Milk Products of the Future", 3-4 April 1973, London.

1/ i.e. babies fed almost exclusively with mother's milk or "humanized" cow's milk.

Table 11

VARIATION OF COMPOSITION OF MATURE HUMAN MILK WITH AGE

(Each figure derived from groups of 11-22 subjects)

Milk component	Age in years		
	22-25	26-31	>32
Nitrogen mg/100 ml	210 ± 14	187 ± 7	186 ± 8
Fat g/100 ml	3.41 ± 0.32	4.29 ± 0.27	3.59 ± 0.32
Lactose g/100 ml	7.55 ± 0.12	7.40 ± 0.14	7.35 ± 0.19

Cuthbertson, W.F.J., see Table 10.

Table 12

REPRESENTATIVE MEAN VALUES FOR FAT CONTENT (g/100 ML) OF MATURE HUMAN MILK

g fat/100 ml	Reference
3.80	Macey *et al.* (1953) Summary of data before 1953
4.77	Kon & Mawson (1950) Reading, U.K.
3.66	Kon & Mawson (1950) Shoreditch, U.K.
3.17	Hytten (1954 c) Aberdeen, U.K.
2.06	Kuboshima (1969) Tohoku, Japan
2.76	Kuboshima (1969) Tokyo, Japan
2.85	Underwood *et al.* (1970) Lahore, Pakistan
3.80	Bonvini *et al.* (1967) Milan, Italy

Cuthbertson, W.F.J., see Table 10.

Infant foods [1/] containing the same concentrations and proportions of the various dietary essentials as human milk, which is the infant food *par excellence*, should be satisfactory. New infant formulations are based on foods of proven value, coupled with a knowledge of the child's metabolism and nutrient needs. It has been stressed, however, that difficulties arise in that the composition of human milk is not constant. Its mean composition varies from woman to woman and from one population to another (29). The data in Table 11 on variation of mature human milk with age and Table 12 on representative mean values for fat content of such milk might serve as examples. In addition, considerable changes have been observed during lactation by any one mother. Hence, there might be difficulties in deciding which are the best compositions and which may be unsatisfactory.

1/ Defined by W.F.J. Cuthbertson (29) as food which can act as the sole source of nourishment from birth to three to six months of age, and which thereafter will normally provide a decreasing proportion of the child's food consumption.

Infant foods should have a nutritional value similar to that of human milk. They often contain a suitable proportion of poly-unsaturated fatty acids. Their calcium phosphorus ratio should be adjusted closely to that occurring in human milk. The Codex Committee on Foods for Special Dietary Uses has developed a draft standard for infant foods based on milk and non-milk proteins, or proteins separated from milk, which contains detailed specifications as regards protein, fat and linoleate, cholin, vitamins and minerals and also provisions dealing with hygiene, labelling etc. (53).

One of the more recent developments consists of the use of a high percentage of whey protein in infant food to bring the composition of the product more closely in line with the composition of human milk where the protein ratio is whey 60 percent and casein 40 percent. (In cow's milk the ratio is whey 18 percent, casein 82 percent). The excessively high mineral content of whey which has precluded its use in infant formulae can now be reduced to a lower level by means of electrodialysis (167) (see also Chapter 5.1).

4.2 Comparison of Milk Products and Imitation Milk Products 1/

An excellent summary of the major differences between milk and milk products and their imitations and the most important pros and cons concerning the distribution of imitation products has been provided by the American Academy of Pediatrics Committee on Nutrition, entitled "Filled Milks, Imitation Milk and Coffee Whiteners" (4). The conclusions and recommendations of this neutral body of scientists read as follows:

> "Imitation milk products or non-dairy 'white beverages' are being developed and evaluated in many countries where milk and other high-quality protein sources are scarce. These efforts to provide nutritional supplements and to extend the available food supplies are to be commended, and research in these areas should not be stifled. If imitation milk products are to replace milk in the diet, they must contain adequate quantities of the essential nutrients to approximate the qualities inherent in milk.
>
> The products available to the American population have not been consistent in offering the same nutritional benefits as fluid milk. Additional information about the qualitative and quantitative composition of these products is needed before physicians in developed countries can unqualitatively accept them.
>
> The use of imitation milks should not necessarily be viewed as a potential nutritional hazard for the population, unless they are substituted as formula for infants. Imitation milks can be used as a more nutritious beverage than many beverages now consumed by children. However, certain nutritional risks are likely if imitation milks are used as a replacement for milk in the diets of children in the absence of other suitable sources of essential protein, minerals and vitamins. The same may be true if these products are used in the belief that they are supplying the same nutrients as skim milk or well formulated filled milks.
>
> Informative labelling and suitable standards are needed to minimize any nutritional hazards that might result from the indiscriminate use of poorly formulated products."

The same publication also contains the following observations as regards consumer awareness of milk substitutes in a certain area in the U.S.A.: 61 percent of those using substitutes believed that milk substitutes were nutritionally equivalent to milk, while only 10 percent of the users thought there was a difference. The remaining 29 percent of these consumers were unaware of the nutritional value of the milk substitutes.

1/ In addition to the literature referred to in the text of Chapter 4.2, the following literature has been consulted: 28, 64, 65, 70, 71, 82, 125, 126, 140, 162.

4.3 Production, Trade and Prices

Production in selected countries. In the IDF survey of 1969/70 on imitation and synthetic milk products1/, information from 22 IDF member countries was received in response to a questionnaire which asked for: description and amount of home production; imports, sales price, legislation, and reasons for use of imitation products. The survey was up-dated by two enquiries carried out by the IDF in 1970 and 1972 respectively (105, 106, 109).

As only IDF member countries were included in the survey, a significant production of filled, evaporated and condensed milk in certain S.E. Asian areas was excluded. Some information on the production of these and other imitation milk products in the United States was, however, given. They will be described after the following summary of the up-dated IDF survey.

Twenty-two major dairy countries responded to the questionnaire: Austria, Australia, Belgium, Brazil, Canada, Denmark, German Fed. Rep., Finland, France, Netherlands, India, Ireland, Israel, Japan, Kenya, New Zealand, Norway, Poland, Sweden, Switzerland, United Kingdom, U.S.S.R. and the following products were available in the countries listed below in Table 13.

Table 13

LIST OF COUNTRIES OUT OF 23 (INCL. U.S.A.) IN WHICH IMITATION AND/OR SYNTHETIC PRODUCTS ARE AVAILABLE (1970/72)

Products	Number	Countries
Imitation Products 1/		
Liquid milk 2/	4	Australia, U.K., U.S.A., Brazil (school milk)
Condensed and evap. milk	2	(S.E. Asia), U.S.A., Netherlands
Milk powder	4	Australia, U.K., U.S.A., Japan
Ice-cream	10	Belgium, Brazil, Canada, Israel, Japan, Netherlands, Sweden, Switzerland, U.K., U.S.A.
Cream	6	Australia, Ireland, Japan, Finland, U.K., U.S.A.
Whipping cream	2	Israel, U.S.A.
Baker's cream	6	Denmark, German Fed. Rep., Norway, Sweden, U.K., U.S.A.
Cheese	5	Japan, Sweden, U.S.S.R., U.S.A., German Fed. Rep.
Infant formula	8	Australia, Kenya, Norway, U.K., U.S.A., Brazil, Denmark, Netherlands
Synthetic Products 1/		
Liquid milk	1	U.S.A.
Condensed and evap. milk	1	U.K.
Cream powder (coffee whiteners, whipped toppings, etc.)	12	Australia, Canada, Denmark, Kenya, Japan, Norway, Netherlands, Sweden, Switzerland, U.K., U.S.A., German Fed. Rep.
Ice-cream	1	Israel
Infant formula	1	Australia
Desserts	2	Canada, U.K.

1/ The definitions used by the IDF apply. See page 4.

2/ Mexico is also an important producer of "filled milk". See page 24.

From the survey, it would appear that the imitation milk products (both "imitation" and "synthetic" products as defined by the IDF) which have gained the greatest prominence are ice-cream substitutes and cream substitutes (in liquid, powder and frozen form).

Ice-cream substitutes are reported to have a high share of the total ice-cream markets of Sweden (90 percent), the U.K. (75 percent), Japan (50 percent), the Netherlands (50 percent) and Belgium (45 percent). In the U.S.A., the market share of imitation ice-cream (Mellorine) was 7 percent in 1969 (15 percent of the frozen dessert market in the 13 states where Mellorine can be sold).

The production of "synthetic" ice-cream was reported only from Israel, probably for religious reasons.

Cream substitutes. In Sweden, about 10 percent of coffee cream sales is covered by substitute coffee whiteners. In the U.S.A. these products took an estimated 35 percent of the market for light cream and substitute toppings have captured more than half the market for whipped toppings (9).

Imitation and synthetic condensed and evaporated milk. Apart from the Philippines and S.E. Asia which were not included in the IDF survey, little development seems to have taken place. In the U.K. the manufacture of a "synthetic plant milk" produced primarily for vegetarians is reported. In the U.S.A. imitation evaporated milk is produced on a relatively small scale.

Imitation and synthetic liquid milk. In the U.S.A. sales of these products are reported to represent no more than 0.3 percent of the market. "Synthetic" milk is reported to have gained little acceptance because of poor flavour (despite the fact that it is cheaper than fresh milk, the retail price being about 75 percent of the price of liquid milk (1969)). A considerable quantity of imitation (filled) milk is produced in Mexico City (250 000 litres are sold daily at subsidized prices) (54).

In India industrial scale trials with a "vegetable toned milk" (Miltone, formerly "Lac-Tone") are carried out with the assistance of UNICEF (25) and in Chile similar trials are in progress with a "milk" based on fish protein and fish oil (45, 50).

Imitation cheese based on skimmed milk with vegetable fat is reported to have captured 2 percent of the Swedish cheese market. In the Japanese product, the fat component has been partly replaced by non-milk fat.

Soybean curd (tofu) was reported to amount to 90 percent of the soy protein consumption in Indonesia and Japan. Some soy protein was used in the U.S.A. (34) in making Cheddar cheese and work on imitation cheese spread based on peanut protein was undertaken in India (150).

As regards international trade in imitation and synthetic milk products, the most important items appear to be imitation creams including coffee whiteners and imitation milk powder, including baby food.

The retail prices for the substitutes are reported to be considerably lower than those of the genuine products, except that the prices given for imitation milk for infant food (in U.K. and Kenya) were reported to be higher than the prices for the milk-based products.

Examples of retail prices and ingredient cost of selected milk products and their substitutes. A comparison of average advertized prices, estimated ingredient cost and marketing margin for selected dairy products and substitutes in the U.S.A. in 1969 is given in Table 14 (142).

Table 14

COMPARISON OF AVERAGE ADVERTIZED PRICES, ESTIMATED INGREDIENT COST AND MARKETING MARGIN FOR SELECTED DAIRY PRODUCTS AND SUBSTITUTES, U.S.A., 1969

Product	Package	Average advertized retail price	Estimated ingredient cost	Marketing margin between ingredient cost and retail price	Marketing margin as percentage of retail price
		cents	cents	cents	percent
Whole milk	½ gallon	50.8	29.1	21.7	43
Filled milk	½ gallon	37.4	20.3	17.1	46
Coffee cream	pint	43.3	19.6	23.7	54
Coffee whitener (liquid or frozen)	pint	20.2	5.4	14.8	73
Coffee whitener (powdered)	½ pound	43.2	8.7	34.5	80
Whipping cream	pint	49.9	29.4	20.5	41
Whipped topping	pint	31.6	4.6	27.0	85
Sour cream	pint	66.8	21.4	45.4	68
Imitation sour cream	pint	45.6	6.9	38.7	85
Ice-cream	½ gallon	67.2	25.0	42.2	63
Imitation ice-cream	½ gallon	41.4	13.3	28.1	68
Ice-milk	½ gallon	49.0	14.7	34.3	70
Imitation ice-milk	½ gallon	36.2	10.0	26.2	72

Moede, H.H., 1970, USDA, Economic Research Service, MTS 177, p. 23.

The comparison shows that, except for coffee cream, the average advertized prices for milk products ranged from 35 to 62 percent above the retail price of the substitutes. The difference in price between coffee cream and powdered coffee whitener being much smaller than that between the other milk products and their substitutes listed in Table 14, it appears that coffee whitener is bought for convenience purposes (storage, shelf life) rather than for the price differential. A comparison of the composition and ingredient cost of selected milk products and their substitutes listed in Tables 15 and 16 shows that significant cost differences exist between the fat component of the milk product and the corresponding substitute product. In the milk products, the cost of fat ranged from 44 to 90 percent of the total ingredient cost. For substitutes it represented 16-28 percent of the total ingredient cost. This is because milk fat was approximately 3.5 times more expensive than vegetable oil and the fact that milk products usually contain more fat than their substitutes. However, the level of fat did not affect the cost difference between the milk products and their substitutes as much as the variation between the cost

of milk fat and vegetable fat. Even in the case of powdered coffee whitener, where the fat content is double the milk fat content of coffee cream, the difference between the cost of the fat used accounts for the major difference in total costs. Owing to the lower cost of vegetable fat, the total ingredient cost of the substitutes is lower than that of the corresponding milk product. Therefore, it must be concluded that unless the price difference between butterfat and vegetable fat is drastically reduced[1/] milk product substitutes will continue to have considerably lower ingredient costs.

While this situation is likely to continue in the foreseeable future, it should not be overlooked that the price ratio of butterfat to vegetable oils has decreased to roughly 2:1 owing to the steeper increase of prices for vegetable oils (see Table 36) as compared with those for butterfat. In July 1972, FAO made the following forecast[2/] for world butter and skim milk powder prices[3/] during 1971-80 compared with 1961-70 (43):

	1971-80[4/]	1961-70
Butter (US$/t)	800-1 000	725
Skim milk powder (US$/t)	400-500	225

To illustrate the present cost situation, the fat and milk-solids-not-fat (SNF) ingredient cost for recombined evaporated milk is compared with that for filled evaporated milk, based on present world market prices for anhydrous milkfat (approx. US$1 600/t), coconut oil (approx. US$1 270/t, see Table 36) and skim milk powder (approx. US$1 000/t)[5/].

Milkfat (7.5%) and SNF (17.5%) cost for recombined evaporated milk: approximately US$ 302/t.

Vegetable fat (7.5%) and SNF (17.5%) cost for "filled" evaporated milk: approx. US$ 277/t.

This means that the ingredient cost for "filled" evaporated milk is less than 10 percent lower than that for the recombined whole milk product.

1/ The price of butter in the EEC in April 1973 was 1860 units of account/t or US$2240/t; i.e. about 6-8 times more expensive than the vegetable oils. (See also prices for vegetable oils Table 35). In May 1974, the world market price of butterfat was only about twice as high as the price for vegetable oils (see page 68).

2/ The forecast that world market prices for these commodities are to average above the depressed level of the 1960s was made on the assumption that the EEC is successful in adjusting supply to market outlets, and that the Community pursues a trade policy which does not frustrate New Zealand's efforts to diversify its export markets.

3/ The price for skim milk powder in the EEC in 1972/73 was 540 units of account (UA)/t, i.e. US$650. As regards the price for butter in the EEC, see footnote 1/.

4/ In terms of 1971 dollars

5/ It is understood that this is a theoretical calculation as in most cases import duties would have to be added to the cost for milkfat and skim milk powder. In addition, part of the fat component would normally be in a lower priced oil.

Table 15

COMPOSITION AND ESTIMATED INGREDIENT COST OF 100 POUNDS OF SELECTED DAIRY PRODUCTS, U.S.A., 1969

Product and estimated ingredient cost	Unit	Milk fat	Fluid skim milk	Other ingredients 1/	Total
Whole milk:					
Composition	lbs	3.5	96.5	-	100.0
Ingredient cost	$/cwt	2.97 2/	3.81 2/	-	6.78
Coffee cream:					
Composition	lbs	18.0	82.0	-	100.0
Ingredient cost	$/cwt	15.29 2/	3.23	-	18.52
Whipping cream:					
Composition	lbs	30.0	70.0	-	100.0
Ingredient cost	$/cwt	25.48 2/	2.76 2/	-	28.24
Sour cream					
Composition	lbs	18.5	80.0	1.5	100.0
Ingredient cost	$/cwt	15.71 2/	3.16 2/	1.05	19.92
Ice-cream					
Composition	lbs	10.0	74.7	15.3	100.0
Ingredient cost	$/cwt	8.05 3/	1.13 3/	1.90	11.08
Ice-milk					
Composition	lbs	4.0	80.5	15.5	100.0
Ingredient cost	$/cwt	3.22 3/	1.22 3/	2.09	6.53

1/ Includes sweeteners, starter cultures, and/or emulsifiers where required.

2/ Based on prices paid by dealers for milk used in fluid products. 1969 average = $6.78 per cwt (3.5 percent B.F.) and a butterfat differential of 8.1 cents which result in the following prices for the 2 components of milk. Nonfat fluid skim = 3.945¢/lb. Butterfat = 84.945¢/lb.

3/ Based on prices paid for manufacturing grade milk. 1969 average= $4.28 per cwt (3.5 percent B.F.) and a butterfat differential of 7.9 cents which result in the following prices for the 2 components of milk. Nonfat fluid skim = 1.515¢/lb. Butterfat =80.515¢/lb.

Moede, H.H., 1970, USDA, Economic Research Service, MTS 177, p. 20.

Table 16

COMPOSITION AND ESTIMATED INGREDIENT COST OF 100 POUNDS OF SELECTED SUBSTITUTES FOR DAIRY PRODUCTS, U.S.A., 1969

Product and estimated ingredient cost	Unit	Vegetable fat	Protein agent	Body and sweetening agent	Other ingredients 1/	Water	Total
Filled milk:							
Composition	lbs	3.0 2/	96.8	-	0.2	-	100.0
Ingredient cost	$/cwt	0.75	3.82 4/	-	0.16	-	4.73
Coffee whitener (liquid or frozen):							
Composition	lbs	10.0 2/	2.3 5/	8.3	0.7	78.7	100.0
Ingredient cost	$/cwt	2.50	1.20	0.97	0.46	-	5.13
Coffee whitener (powder):							
Composition	lbs	36.0 2/	5.0 5/	56.0	2.0	1.0	100.0
Ingredient cost	$/cwt	9.00	2.62	5.43	0.44	-	17.49
Whipped topping:							
Composition	lbs	25.0 2/	2.5 5/	12.0	0.8	59.7	100.0
Ingredient cost	$/cwt	6.25	1.31	1.31	0.30	-	9.17
Imitation sour cream:							
Composition	lbs	18.0 3/	4.0 5/	5.0	0.5	72.5	100.0
Ingredient cost	$/cwt	3.15	2.09	0.58	0.56	-	6.38
Imitation ice cream (mellorine):							
Composition	lbs	10.0 2/	72.6 6/	17.0	0.4	-	100.0
Ingredient cost	$/cwt	2.50	1.10	1.78	0.51	-	5.89
Imitation ice milk:							
Composition	lbs	4.0 2/	77.2 6/	18.5	0.3	-	100.0
Ingredient cost	$/cwt	1.00	1.17	1.91	0.35	-	4.43

1/ Includes buffering, emulsifying, and stabilizing agents
2/ Coconut oil
3/ Soybean oil
4/ Fluid skim milk Class I price of 3.945¢/lb
5/ Sodium caseinate
6/ Fluid skim milk for manufacturing use price of 1.515¢/lb

Moede, H.H., 1970, USDA, Economic Research Service, MTS 177, p.21.

4.4 Estimates of Demand Substitution by Imitation Milk and Imitation Milk Products in 1980

The impact of milk substitution is likely to be greatest in the market for processed milk 1/ and little substitution is likely to occur in the raw milk market.

The impact which imitation milk might have on the consumption of milk and milk products appears to be of particular interest to the dairy industry in developed countries where the proportion of locally produced milk undergoing heat treatment and processing is already high, amounting to 90 percent or more in North-West Europe, Australia, New Zealand and North America, and 50 to 65 percent in Eastern Europe and the U.S.S.R.

However, the estimates on milk processing in developing countries contained in Table 17 show that by 1980 nearly a quarter, and by 1990 almost one-third of the milk produced in developing countries might be processed. The Latin American region is expected to surpass the 50 percent mark in the early 1980's (44).

One reason for increased production of imitation milk and milk products is the high retail price for milk and milk products in these countries and the low purchasing power of large groups of their populations. The desire for reducing milk product imports to save foreign exchange, while at the same time wishing to raise the standard of nutrition, might also induce governments to import and/or produce imitation milks. This may result in the exploitation of the potential for oilseed production as a source of fat and protein for imitation milk and milk products. In countries with petroleum and/or gas resources to utilize, this potential might also be used for the manufacture of single cell protein (SCP) for animal feeding, releasing oilseed protein for human consumption, including imitation milks. The use of SCP for human food might also be considered by some governments as a long-term objective. The pressure of increasing population on the land available for agricultural purposes in the more densely populated areas of the world (Far East) might discourage governments from giving high priority to the development of a dairy industry based on local milk production. They might instead support the establishment of a food industry using local fat and protein products., As a consequence, governments may have no particular interest in protecting local milk production and they may also not be prepared to issue restrictive legislation against imitation milk and milk products. The suspension of the Filled Milk Act in the U.S.A. might also induce governments to take a liberal attitude towards "filled" milks. On the other hand, taking into account the projected large gap between demand and output in developing countries, imitation milks might close part of the projected gap rather than directly affect local milk production in these regions 2/. There would also be sufficient supply for increased "filled" milk production if alternative sources of protein feed for animals become more readily available, such as SCP, and more milk could be released for human consumption. In Western Europe alone over 1 million tons of skim milk powder and almost 10 million tons of liquid skim milk are presently fed to calves and pigs.

The assumed medium level of use of imitation milk and milk products (see Table 18) could occur under changes of technology, marketing practices and regulations that would create more favourable manufacturing and marketing conditions for these products.

The high level of use of imitation milk and milk products assumes far-reaching changes in the technology of producing milk substitutes, no legal restrictions, cheap raw materials for milk substitutes, and good consumer acceptance of the imitation products.

1/ i.e. milk passing through milk plants for heat treatment and for processing into milk products.

2/ According to FAO Agricultural Commodity Projections made on the assumption of constant prices and policies, demand for milk and milk products will exceed production by some 20 million tons of milk equivalent on the world level in 1980 with the gap in the developing countries alone reaching some 15 million tons.

Table 17

MILK PROCESSING IN DEVELOPED COUNTRIES

	Estimated milk processed 1970			Projections of milk processing 1980			Projections of milk processing 1990		
	Milk production million tons	Processing		Milk production million tons	Processing		Milk production million tons	Processing	
		% of production	mill. tons		% of production	mill. tons		% of production	mill. tons
Africa	5.6	5	0.3	7.5	10	0.8	10	17	2
Asia	37.0	5	1.9	46.3	10	4.6	59	17	10
Latin America	24.0	40	9.6	34.2	47	16.1	44	55	24
Near East	12.4	10	1.2	16.7	15	2.5	21	20	4
	79.0	16	13.0	104.7	23	24.0	134	30	40

FAO, Commodities and Trade Division, Milk and Milk Products Team, 1973, Working Paper World Market Outlook for Milk Products, DDI:G/73/31 - Industry Cooperative Programme.

Table 18

ESTIMATED MEDIUM AND HIGH LEVEL MARKET PENETRATION OF, AND/OR DEMAND SUBSTITUTION, BY IMITATION MILKS AND IMITATION MILK PRODUCTS IN 1980
BASED ON FAO DEMAND PROJECTIONS FOR MILK AND MILK PRODUCTS 1980 (CCP 71/20-EXTRACT SEPT. 71)

Milk and Milk Products (whole milk equivalent mill. tons)		Western Europe	Eastern Europe	U.S.S.R.	U.S.A.1/	Africa	Latin America	Near East	Asia & F. East	Oceania	World
Projected demand	Food	121.55	37.85	91.90	54.00	9.11	35.60	19.00	56.27	8.59	462.02
	Total	132.25	42.90	107.40	54.50	9.45	37.18	19.7	57.57	8.79	498.66
Projected production		126.48	43.63	110.00	52.50	7.54	34.15	16.7	46.28	15.10	478.66
Projected trade balance (exports (-))		5.77	-0.73	-2.60	2.00	1.91	3.04	3.0	11.29	-6.31	20.00
Amount of milk and milk products replaced assuming medium level of substitution 1/ (1.5%)					(2.7%)						
Estimation based on: (i) projected demand for food		1.83	0.57	1.38	1.42	0.14	0.54	0.29	0.83	Total	7.00
(ii) estimated amount of processed milk 2/		1.83	0.43	1.08	1.42	0.01	0.24	0.04	0.07	Total	5.12
Amount of milk and milk products replaced assuming high level of substitution 1/ (5%)					(8.8%)						
Estimation based on: (i) projected demand for food		6.07	1.90	4.59	4.60	0.46	1.78	0.95	2.81	Total	23.16
(ii) estimated amount of processed milk 2/		6.07	1.42	3.60	4.60	0.04	0.80	0.12	0.23	Total	16.88

1/ U.S. figures for market penetration are based on Synthetics and Substitutes for Agricultural Products, Projections for 1980, USDA, Marketing Research Report No. 947, 1972. The projected levels of penetration are 2.7% (medium) and 8.8% (high); "Assumed levels of market penetration by dairy substitutes, 1980" are listed in Table 19.

2/ Proportion of processed milk to total milk production in 1980 in:

Africa	10%	(0.8 million tons)
Lat. America	47%	(16.1 " ")
Near East	15%	(2.5 " ")
Asia	10%	(4.6 million tons)
Western Europe	90%	(i.e. practically the amount for food)
U.S.S.R. & E. Europe	65%	(i.e. 71.5 million tons and 28.4 million tons respectively)

It is likely that in developing countries with a milk recombination industry, imitation milk products would first penetrate the sector of recombined milks (replacement of butterfat imports by locally produced vegetable oils (92)) rather than affect local (raw) milk production.

The substitution of milk and milk products in Oceania is estimated to be negligible because of the low retail prices for milk and milk products and the market protection measures which are likely to be implemented in Australia and New Zealand should attempts be made to introduce substitutes.

An example for assumed levels of market penetration by individual imitation milk products by 1980 for the U.S.A. (75) is given in Table 19.

Table 19

ASSUMED LEVELS OF MARKET PENETRATION BY DAIRY SUBSTITUTES IN THE U.S.A., 1980

Dairy Product	Level of penetration in %	
	Medium	High
Fluid whole milk	3	10
Cream	10	25
Low-fat milk	3	10
American cheese	3	10
Other cheese	3	10
Evap. whole milk	2	7
Cond. whole milk	2	7
Ice-cream	3	10
Ice-milk	3	10

USDA, Economic Research Service, Mark. Res. Report No. 947, p. 57.

5. EXISTING AND POTENTIAL PROTEIN RAW MATERIALS FOR THE MANUFACTURE OF IMITATION MILK AND IMITATION MILK PRODUCTS

5.1 Animal Protein

Products derived from milk and from fish

- skim milk in liquid, condensed or powdered form;
- casein, caseinates and co-precipitates;
- whey in liquid, condensed, powdered form; and whey proteins;
- fish protein.

Skim milk

The annual averages of world market prices and wholesale prices in the U.S.A. and the EEC for milk products given in Table 20 indicate considerable fluctuations during the recent years. The world market price for skimmed milk powder 1/ increased from US$ 120/t at the end of 1969 to approximately US$ 650/t at the end of 1971, decreased to approximately US$ 620/t in March 1972 and further to US$ 450-500/t in March 1973, reaching approximately US$ 700/t at the end of 1973/beginning 1974 and stand at approximately US$ 1000/t in April 1974. The table also shows the significant differences between the world market prices for these products and the U.S.A. and EEC wholesale prices.

This means that at national level the cost of skim milk powder might be considerably higher than on the world market as the price will largely depend on national policies.

The technological suitability of skimmed milk for "filled" milk and "filled" milk products and for other products, in particular for infant foods, has been clearly established. The author does not know of any significant technological problems concerning the use of skimmed milk in this respect.

A non-acceptance of an imitation milk or imitation milk products could hardly be related to the use of skimmed milk, unless a produce of inferior or unsuitable quality and/or a faulty technology was used.

Edible casein, caseinates and co-precipitates

Preliminary definitions for edible acid casein and edible caseinates have been suggested by the FAO/WHO Committee of Government Experts in draft compositional standards No. A-12 and No. A-13 2/. They read as follows:

1/ Minimum compositional requirements for skimmed milk powder are given in FAO/WHO standards No. A-5 contained in the 7th Edition of Code of Principles Concerning Milk and Milk Products (Ref. No. CAC/M 1/1973).

2/ Report of the 16th Session of the FAO/WHO Committee of Government Experts on the Code of Principles concerning Milk and Milk Products, Rome, Sept. 1973 (Ref. No. CX 5/70, 16th) Appendices VII-A and VII-B).

"Edible acid casein is the product obtained by weighing, pressing and drying the lactic or mineral acid precipitated coagulum of skimmed milk."

"Edible caseinate is the product obtained by drying aqueous solutions prepared by combining dry edible casein or fresh edible casein curd with food grade alkali."

For rennet casein and rennet/acid casein the definitions would be similar to the one for acid casein, except that the coagulum is formed by the action of rennet or rennet and acid.

Commercial manufacture of co-precipitates (i.e. proteins precipitated by acid or calcium chloride from heated milk, comprising both casein and whey proteins) was mainly motiviated by (i) the desire to improve protein recovery from milk (as recovery is only approximately 80 percent when casein is manufactured); (ii) to increase the range of functional properties in milk proteins for foods and (iii) to increase the nutritive value of the product by incorporating whey proteins. Several processes have been developed in the United States, the U.S.S.R. and in Australia producing co-precipitates with varying functional properties such as solubility and wettability (145).

World casein production (including caseinates) amounts to approximately 140 000 t/year (1973).

The world market price for casein was US$ 1 200/t in March 1972, decreased to approximately US$ 1 000/t in April 1973 and increased again at the end of 1973/beginning 1974 to approximately US$ 1 200/t (see Table 20).

As long as prices for skim milk powder are high, and with increasing cheese production, prices for edible casein and caseinates are unlikely to decrease in the foreseeable future. The products are also in high demand because of their excellent qualities as ingredients in many food products other than imitation milk and imitation milk products.

The success of the "coffee whiteners" and of the "whipped toppings" shows that casein and caseinates are being considered as economically and technologically suitable by industry. (It has been estimated that in the U.S.A. 90 percent of the imitation liquid coffee whiteners is manufactured by the dairy industry whilst 90 percent of the imitation whipped creams and frozen toppings is handled by other food companies. Approximately 6 500 t of caseinates were used in the U.S.A. in 1971 for coffee whiteners and whipped toppings). Edible casein and caseinates have a bland taste and do not impart any detectable flavour to the products in which they are used. Even the flavour of imitation milk with sodium and calcium caseinate as a protein source has been found reasonably acceptable (probably due to rather low caseinate percentage in the formula). Co-precipitates have been used in Australian milk biscuits and in infant food for lactose-intolerant patients (145).

Although casein and caseinate have a high nutritional value, this is lower than that of milk protein which contains the whey protein fraction in addition to casein (see also Table 37).

Whey powder and whey proteins

Whey, as defined by the Whey Products Institute, Chicago, Illinois (192) "is the fluid obtained by separating the coagulum from milk, cream and/or skim milk". As a by-product of cheese or casein manufacture, the composition of whey and whey products is determined by the method of curd formation (i.e. by the action of rennet and/or lactic acid fermentation, depending on the type of cheese being made and by lactic acid, mineral acid or rennet precipitation, depending on the type of casein produced), curd handling and by the method of handling the whey after it is separated from the curd.

Table 20

PRICE OF SELECTED DAIRY PRODUCTS FOR COUNTRIES SHOWN

	1969	1970	1971	1972	1973	1969	1970	1971	1972	1973
	National currency					US$/ton				
Skim milk powder										
United States US¢/lb	23.50 1/	26.30 1/	31.30 1/	32.45 1/	45.56 1/	518	580	690	715	1 004
EEC Gld/kg	1.50 4/	1.52 4/	1.85 4/	1.98 4/	2.22 4/	414	420	528	617	785
World market price Can $/ton	162.88	215.86	379.42 7/	593.15 7/	618.36 7/	151	206	376	598	618
Whey powder										
United States US¢/lb	5.15 2/	5.27 2/	5.18 2/	5.56 2/	7.65 2/	114	116	114	123	169
EEC Gld/kg	0.50 5/	0.49 5/	0.70 5/	0.70 5/	0.77 5/	138	135	200	218	272
World market price Can ¢/lb	5.50 8/	5.50 8/	5.75 8/	5.65 8/	6.36 8/	112	116	126	126	140
Casein										
EEC £/ton	225 6/	238 6/	n.a.	477 6/ 3/	455 6/	540	571	n.a.	1 193	1 122

Notes:
1/ Skim milk powder, spray - Wholesale f.o.b. Chicago area.

2/ Whey powder, roller - Wholesale - New York area.

3/ 1972 quotations only from September.

4/ Dutch domestic market price - Wholesale
5/ Dutch whey powder, spray - Wholesale
(*1969, 1970 = 0.2762 US$ = 1 Gld; 1971 = 0.2854 US$ = 1 Gld; 1972 = 0.3116 = 1 Gld; 1973 = 0.3537 = 1 Gld.

6/ New Zealand 1st grade c.i.f. UK (*1969, 1970 = 2.400 US$ = £1; 1971 = 2.432 US$ = £1; 1972 = 2.502 US$ = £1; 1973 = 2.452 US$ = £1)

7/ Canadian f.o.b. (*1969 = 0.9250 US$ = 1 C$; 1970 = 0.9552 US$ = 1 C$; 1971 = 0.9903 US$ = 1 C$; 1971 = 0.9903 US$ = 1 C$; 1972 = 1.0095 US$ = 1 C$; 1973 = 0.999 US$ = 1 C$)

8/ Whey powder, roller - Wholesale, Montreal area

FAO Commodities and Trade Division, April 1974.

*Exchange rate.

The bulk of whey produced is derived from cheese making. Fresh cheese whey contains 6.5 to 7 percent total solids, i.e. more water than skim milk, practically the same amount of lactose, about half the calcium and phosphorus, three-fourth as much riboflavin but only one-fourth as much protein (133). The composition of liquid and dried cheese whey and skim milk is given in Table 21.

Table 21

COMPOSITION OF LIQUID AND DRIED SKIM MILK AND WHEY

(amount per 100 g)

Item	Unit	Liquid skim milk	Liquid whey	Skim milk powder	Whey powder	Dried whey solids 1/	
						Sweet	Acid
Water	Percent	90.5	93.1	4.0	4.5	...	...
Protein	g	3.6	0.9	35.8	12.9	13.5	11.8
Fat	g	0.1	0.3	0.7	1.1	1.2	...
Lactose	g	5.1	5.1	51.6	73.5	74.5	69.7
Ash	g	0.7	0.6	7.9	8.0	8.4	7.8
Calcium	mg	121	51	1 293	646	...	...
Phosphorus	mg	95	53	1 005	589	...	...
Iron	mg	trace	0.1	0.6	1.4	...	...
Sodium	mg	52	...	526	...	...	...
Potassium	mg	145	...	1 725	...	...	...
Vitamin A	Internat.Units	trace	10	30	50	...	...
Thiamin	mg	0.04	0.03	0.35	0.50	...	...
Riboflavin	mg	0.18	0.14	1.78	2.51	...	...
Niacin	mg	0.1	0.1	0.9	0.8	...	...
Ascorbic acid	mg	1	...	7	...	...	...
Food energy	cal.	36	26	359	349	...	...
Lactic acid	g	...	...	...	...	2.4	10.7

1/ Pallansch, M.J., Chemical Problems in Whey Utilization, talk at the Whey Utilization Conference, University of Maryland, June 3, 1970. Composition of Foods, Agricultural Handbook Number 8, USDA, 1963.

Mathis, A.G., 1970, USDA, Economic Research Service, DS-332, September 1970, 26-32.

Owing to the expanding cheese production, whey supply has been growing rapidly in North America, Europe and Oceania (see Table 22). On the other hand, returning liquid whey to farmers appears to be on the decline in most developed countries as antipollution laws are more strongly enforced. Hence, the disposal problem is becoming increasingly acute with the result that cheese and casein manufacturers have to process the whey or install effluent treatment facilities. Cheese whey has a biochemical oxygen demand of 30 000-40 000 p.p.m., compared with 100 000-120 000 p.p.m. for whole milk, i.e. the pollution effect of whey (mainly due to its lactose content) is roughly one-third of that of whole milk. Because of transport costs it would be uneconomic to ship whey over large distances. In the Netherlands, for example, all whey is concentrated in the cheese plants before it is transported to drying plants for further processing (18). Mathis (133) reported in 1970 that in an efficient plant the cost of drying and marketing whey has been about the same as the price obtained for animal feed.

Table 22

ESTIMATED WORLD WHEY PRODUCTION 1/

	Source of whey	1966	1971	1972	1973 (prel.)
		................'000 tons................			
U.S.A.	cheese	6 728	8 608	9 449	9 621
	cottage cheese	1 890	2 275	2 355	2 215
	total	8 618	10 883	11 804	11 836
Canada	cheese	704	888	904	810
	cottage cheese	70	110	115	125
	total	774	998	1 019	935
Belgium-Luxemburg	cheese	232	200	192	150
	cottage cheese	50	90	90	80
	total	282	290	282	230
Denmark	total	1 000	960	1 048	1 024
France	cheese	4 328	4 728	5 040	5 176
	cottage cheese	550	875	920	960
	total	4 878	5 603	5 960	6 136
Germany, Federal Republic	cheese	1 472	1 840	1,992	2 008
	cottage cheese	1 040	1 445	1,490	1 560
	total	2 512	3 285	3,482	3 568
Ireland	total	136	264	364	328
Italy	total	3 912	3 840	3 880	3 960
Netherlands	total	1 864	2 424	2 504	2 616
United Kingdom	total	872	1 296	1 469	1 447
Total EEC	total	15 456	17 962	18 989	19 309
Other western Europe	total	4 649	5 083	5 200	5 232
Total western Europe	total	20 105	23 045	24 189	24 541
Australasia	total	1 352	1 440	1 502	1 512
Other developed countries	total	496	768	800	832
Total developed countries	total	31 345	37 134	39 314	39 656
U.S.S.R.	total	3 456	3 624	3 808	4 016
Eastern Europe	total	4 968	6 088	6 090	6 300
Total developing countries	total	17 344	19 344	19 736	20 723
Total World	total	57 113	66 190	68 948	70 695 2/

1/ Estimated at 8 kg and 5 kg of whey per kg of cheese and cottage cheese, respectively.

2/ In addition to whey from cheese and cottage cheese making, there were over 3 million tons of whey from casein production in 1973, with New Zealand, Australia, France, Federal Republic of Germany, Argentina, Poland and the U.S.S.R. being the main producers.

Krostiz, W. and Zegarra, F., 1974, Whey - an under utilized protein source, FAO Commodities and Trade Division, Working Paper DDI:G/74/36.

A world output of whey of approximately 74 million tons in 1973 (71 million tons of cheese whey and 3 million tons casein whey) (see Table 22) would provide about 330 000 tons of heat-coagulable protein and it must be considered unfortunate that, in spite of the chronic protein shortage in several parts of the world, large quantities of whey are still wasted (68). However, the increasing prices for whey powder have strengthened the trend to whey processing rather than its treatment for sewage. As can be seen from Tables 20 and 23, whey powder prices increased significantly in 1973 in line with the world-wide rise in prices of protein commodities. At the beginning of 1974 whey powder prices in the EEC (US$ 0.37/kg spray powder) were about 70 percent higher than in 1973 but, in relation to skim milk powder prices, whey powder prices have been more stable in Western Europe and have even declined in the United States. The considerable increase of whey powder production in developed regions is reflected in the data given in Table 24. They show that in the EEC, the world's leading cheese producing area, about 30 percent of the total whey supply is at present dried. While this percentage is still lower than the 75 percent of skim milk dried from the EEC's total skim milk output, it is four times more than it was in 1966.

Table 23

WHEY POWDER WHOLESALE PRICES AND WHEY POWDER: SKIM MILK POWDER PRICE RATIOS

		1969	1970	1971	1972	1973	
		.... national currency				....	US$/kg
Netherlands							
a) whey powder, spray	guilders/kg	0.50	0.49	0.70	0.70	0.77	0.28
b) skim milk powder, spray, for food	" "	1.50	1.52	1.85	1.98	2.22	0.79
c) skim milk powder, spray, for feed (= b minus EEC subsidy)	" "	1.20	1.22	1.42	1.40	1.43	0.51
a) as percentage of b)	%	33	32	38	35	35	35
a) as percentage of c)	%	42	40	49	50	54	54
U.S.A.							
a) whey powder, spray, for food	cents/lb	8.05	7.83	7.76	8.62	11.74	0.26
b) whey powder, roller, for feed	cents/lb	5.15	5.27	5.18	5.56	7.65	0.17
c) skim milk powder, spray, for food	cents/lb	23.50	26.30	31.30	32.45	46.38	1.02
a) as percentage of c)	%	34	30	25	27	25	25

Krostitz, W. and Zegarra, F., 1974, FAO Commodities and Trade Division, Whey - an under-utilized protein source, Working Paper DDI:G/74/36.

Table 24

WHEY POWDER PRODUCTION

	1966	1970	1971	1972	1973 2/	whey drying as % of total whey supply 1973
	.... '000 tons					%
U.S.A., total	214	282	308	346	338	40
of which for food	110	133	145	171	178	...
Canada	19	20	24	25	24	36
EEC	93	210	274	325	389	30
of which France	26	80	115	148	170	39
Netherlands	28	51	65	71	99	53
Germany, F.R.	15	43	48	56	66	26
United Kingdom 1/	11	13	14	15	15	15
Belgium	6	7	10	9	9	55
Others	7	16	22	26	30	6
Austria	1	7	8	9	11	35
Finland	6	12	14	17	17	65
Total 13 countries	333	531	628	722	779	34

1/ Including butter milk powder.

2/ Preliminary.

Krostitz, W. and Zegarra, F., 1974, FAO Commodities and Trade Division, Whey - an under-utilized protein source, Working Paper DDI:G/74/36.

At present, liquid whey supply levels, an increase in the proportion of whey dried to 50 percent of the total whey supply would mean a production of 1.3 million tons of whey powder in North America and Western Europe alone. It has been estimated (121) that a (moderate) annual rise of 2 percent in cheese production and an increase of dried whey to two-thirds of the liquid supply would result in a whey powder output of nearly 2.5 million tons annually in ten years and a production from developed and centrally planned countries together of approximately 3 million tons. In terms of crude protein content (400 000 t) this would equal 1 million tons of soybeans or 0.6 million tons of fishmeal. Taking into account that world demand for fishmeal and oilcakes alone has been growing at an annual rate of 1 million tons of crude protein, the extra supply would be small in relation to total supply and demand in the feedstaff sector. Moreover, it is likely that the whey powder boom will lead to the substitution of part of the skim milk powder so far fed to livestock. While in 1973 in the EEC alone 1.2 million tons of skim milk powder were fed to calves at heavily subsidized prices, export supplies fell short of the growing demand for skim milk powder, resulting in sharp price increases during the second half of 1973 and food aid shipments to developing countries were probably the lowest for the last fifteen years. A gradual substitution of 15 to 20 percent of these 1.2 million tons would increase the EEC's skim milk powder supply for export and food aid by approximately 200 000 tons. Such a substitution could absorb an additional 600 000 tons of whey powder, about the same as the possible increase in whey powder output in the early 1980's. So far, the bulk of whey powder used has gone into the feed sector, except in the U.S.A. where the use of dried whey for human food accounted for 53 percent of the total United States whey powder production 1/.

1/ In the U.S.A. the use of liquid and dried skim milk for feed purposes has been negligible for many years and the rapid increase in skim milk powder prices in recent years as a result of declining domestic output has facilitated the substitution of whey powder for skim milk powder in the food industry.

More modern technologies of whey processing (186) aim at upgrading whey for human food applications by increasing the protein content relative to lactose and inorganic salts. This can be achieved by precipitation of whey proteins by heat and adjusting the pH of the whey to the isoelectric point and concentrating the denatured whey protein by centrifugation. The Alfa-Laval Centriwhey-process is based on this principle. The concentrate, which contains 15 to 18 percent total solids (10 to 12 percent protein) can either be dried or added to the cheese milk to increase the yield (3, 30, 88). Drying a protein concentrate with 18 percent total solids (10 percent protein) results in a powder with a protein content of 53.5 percent (96 percent total solids).

A new method of processing used for recovery of proteins from whey is gel filtration (127) (see Fig. 2). It separates the proteins from the lactose salt fraction. The gel filter absorbs 2.5 times its dry weight of water and when it is soaked in water it swells to about 5 times its dry volume, the "mesh" of the gel filter getting bigger than lactose and salt molecules but much smaller than protein molecules. This is the reason for its filter effect which is the reverse of a common filter for coarse and small particles. When a mixture of protein, lactose and salt molecules is forced through a gel bed by water under pressure, the small molecules penetrate into the gel beads and are retained for a while inside the "mesh" whereas the big molecules pass through the gel bed more quickly. Thus, fractions of proteins and lactose/salt respectively are obtained.

The filter capacity can be increased by preconcentration (evaporation) or separation of lactose before filtration.

Recently, membrane processes have received considerable attention (67, 96, 97, 120, 135, 146, 156). Two related processes, namely reverse osmosis (RO) and ultrafiltration (UF), are based on the ability of polymeric membranes to discriminate between molecules of different sizes and/or chemical composition. As its name indicates, RO reverses the normal osmotic process (where water and a solution are separated by a membrane, the water passing through the membrane to dilute the solution). In RO pressure is used to drive the water from the solution through a membrane which is a synthetic polymer made of a cellulose derivative or other material. Macromules (i.e. proteins) and salts are retained, water permeates (see Fig. 3).

The same principle is used in UF, except that the process employs much lower pressure and that the membranes have pores of a different size. In the UF process large molecules (i.e. proteins) are retained whereas salts and water permeate (see Fig. 4).

A further membrane process, electrodialysis, employs ion-selective dialysis membranes (100, 157, 175). Electrodialysis is used to remove minerals (ionic groups) from whey. Cation transfer membranes and anion transfer membranes are arranged in units consisting of diluting cells (relative to salts) through which the whey is pumped repeatedly, and waste cells (concentrating the ions). By application of direct current the cations and anions respectively of the whey are removed through the selective membranes into the waste streams (concentrating solutions) (see Fig. 5).

Finally, possibility of using whey (after removal of the protein) for the production of yeast protein should be mentioned (see also Chapter 5.4).

It is obvious that the processes briefly described above can be combined, e.g. desalting by electrodialysis and subsequent drying of whey, or protein separation by UF, electrodialysis of the permeate and its subsequent processing into lactose.

Economics of whey processing

Recently G. Damerow (30) has published data on production costs of a number of whey-derived products based on processing 100 000 l of whey per day in three shifts, except for whey powder manufacture, which was based on 230 000 l/day (20 h run). Damerow's cost estimates (see Table 25) were based on the following investment and variable costs:

FIG. 2: GEL FILTER MODEL

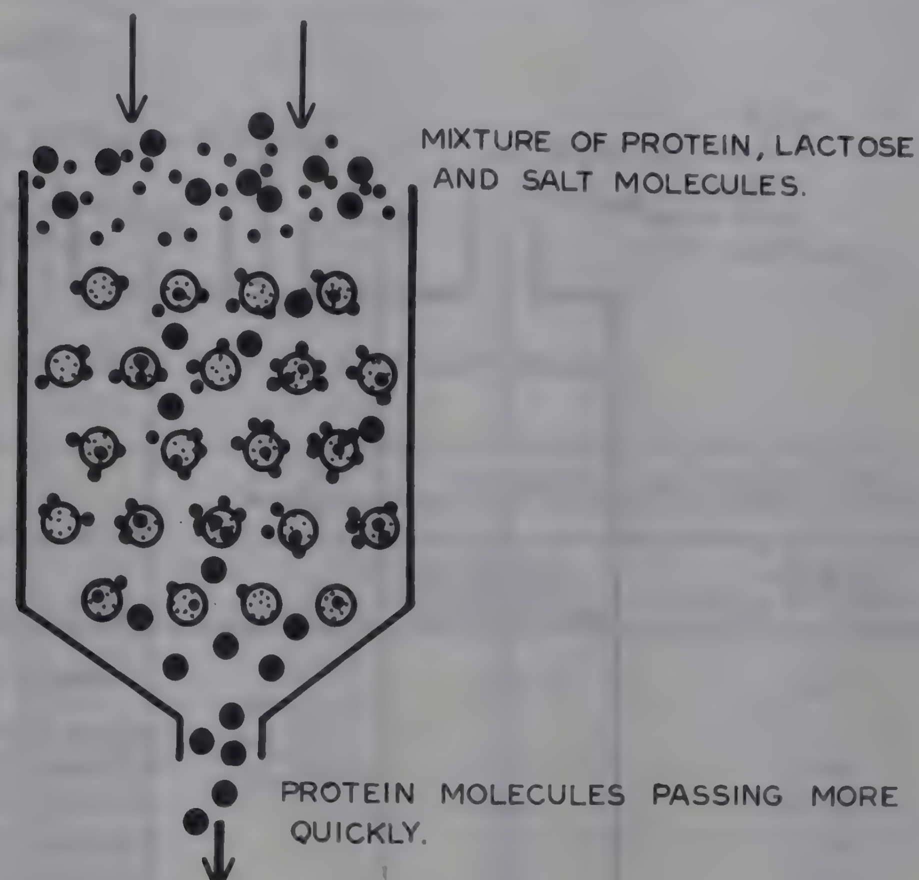


FIG.3: REVERSE OSMOSIS

FIG.4: ULTRAFILTRATION

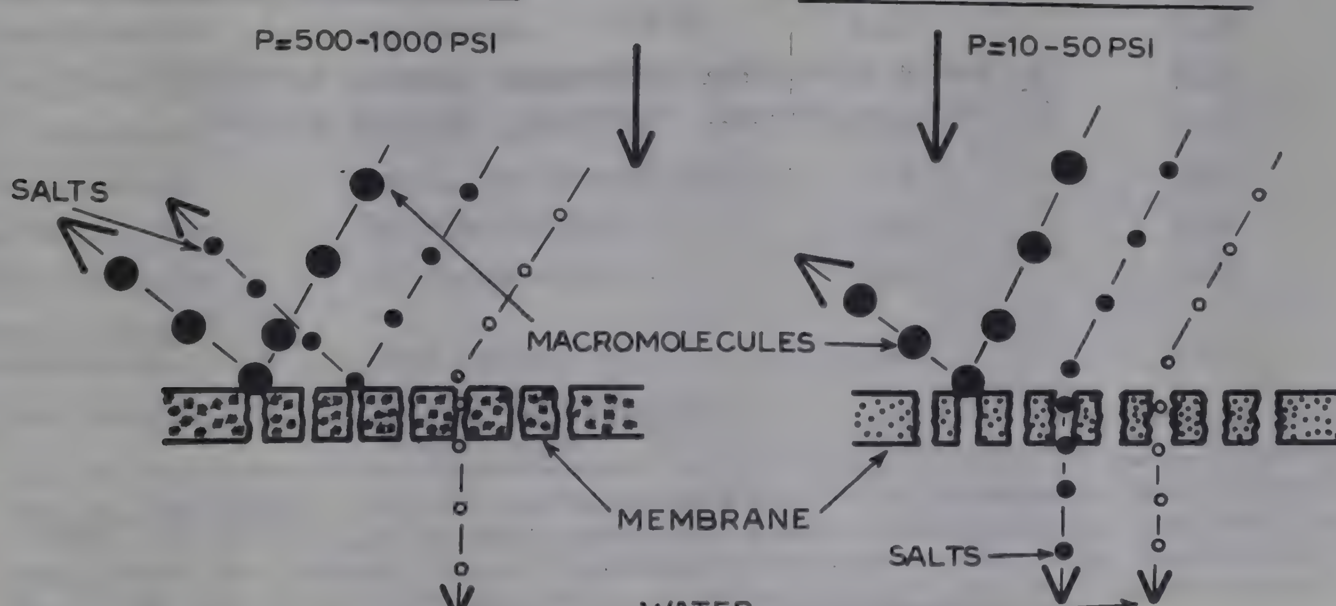
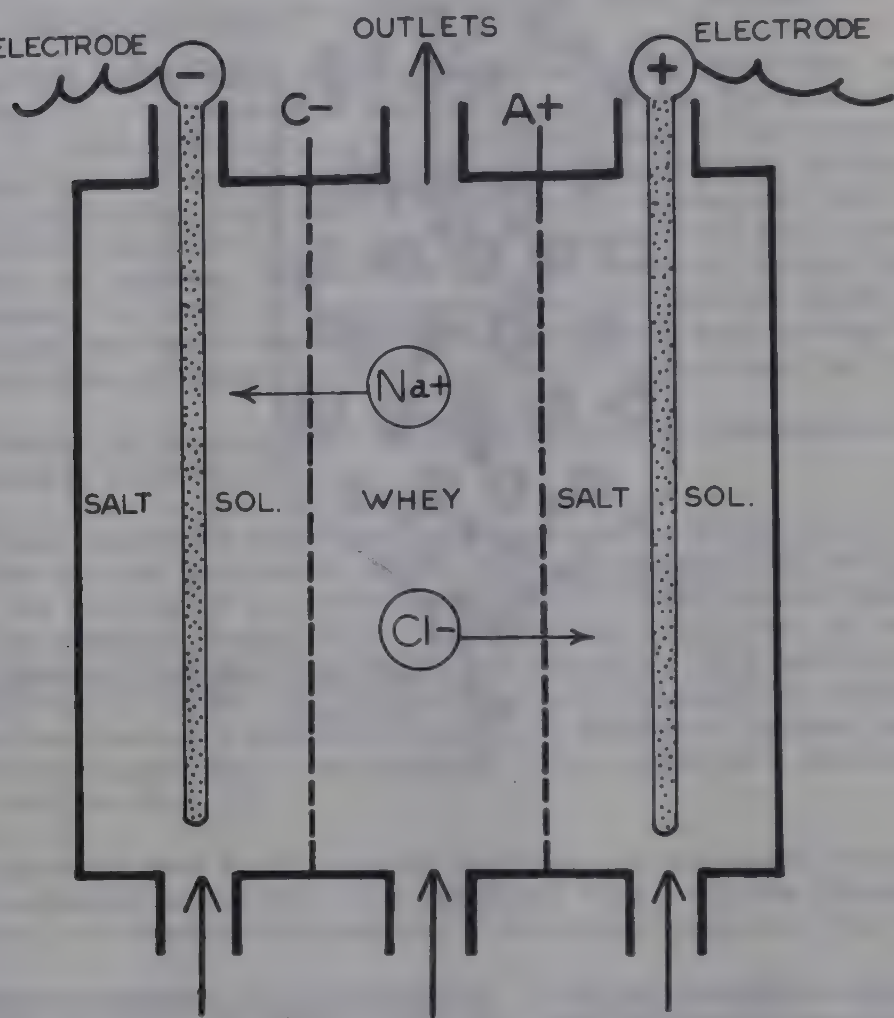


FIG. 5: DEMINERALIZATION BY ELECTRODIALYSIS



A+: ANION PERMEABLE MEMBRANE, (REPELS CATIONS)
C−: CATION PERMEABLE MEMBRANE, (REPELS ANIONS.)

Investment costs

Depreciation (equipment)	10 years
Interest on capital 1/2 the price of equipment	6 percent
Maintenance	2 percent
Taxes	1 percent

Variable costs

Electricity	0.12 DM/kWh
Water and effluents	1.2 DM/m^3
Steam	15.- DM/t
Cost of personnel	10.- DM/h
Operating time	260 days/year

Table 25

PROCESSING COSTS OF WHEY-BASED PRODUCTS

Process	Final product	Processing costs (April 1973) (evaporation, precipitation, filtration, drying) of product (DM/kg)	of whey (Pf/kg = 1/100 DM/kg)
Drying	Whey powder	0.35 1/	2.17
Precipitation by temperature + hydrochloric acid	Protein powder 53% protein	1.00	1.09
	74% protein	1.26	1.37
temperature + lactic acid	53% protein	1.46	1.59
	74% protein	1.86	2.07
	protein concentrate addition to cheese milk soft and semi soft cheese	-	1.30
	protein concentrate addition to Quark (curd)	0.45	1.12
Ultrafiltration	protein powder with 60% protein	2.28	2.97
Ultrafiltration	70% protein	2.67	2.98
Ultrafiltration	protein concentrate 12%	0.39	2.59
Gel filtration	protein powder 70%	5.09	3.46
Gel filtration	protein concentrate 12%	0.74	3.19
Electrodialysis	50% demineralized	0.064	0.40
Electrodialysis	75% demineralized	0.096	0.60
Yeast protein manufacture	yeast protein 88%	1.38	2.47
Lactose manufacture	lactose, food quality + freight costs	0.77	2.57

1/ Note by the author: DM 0.35 correspond to US$ 0.13 (at an exchange rate of DM 2.55 per 1 US$). If the cost of the raw material was added to the processing cost for 1 kg of whey powder at a rate of 0.3 -2 (depending on transport costs) Pf/kg whey or 3.9 Pf - 32.6 Pf/kg whey powder, the processing plus raw material cost of 1 kg whey powder could be DM 0.39 - 0.68 or US$ 0.15 - 0.27 (see also Table 23).

Damerow, G., 1973, Deutsche Milchwirtschaft 31/32, p. 1215-1218 and 1245-1257.

According to Damerow (30) (April 1973, Fed. Rep. of Germany) investment costs for the centri-whey equipment of capacities of 5 000 l and 10 000 l whey respectively per hour are in the order ot DM 200 000 (US$ 79 000) and DM 370 000 (US$ 142 000), respectively. If the whey protein is subsequently dried investment costs for a complete unit consisting of protein recovery and drying for 100 000 l whey/day, processed in 12 hours (including cleaning and maintenance) are approximately DM 550 000 (US$ 215 000). Investment costs for UF equipment, capacity 100 000 l whey/day (including concentration and drying of the protein fraction) resulting in 1.3 t protein powder/day are in the order of DM 1.5 million (US$ 590 000), and for gel filtration (including evaporation and drying of the protein fraction) of the same capacity DM 1.7 million (US$ 630 000).

Investment costs for lactose equipment with a capacity of 20 000 l/h for 20 h/day (i.e. 400 000 l/day) would be approximately DM 2.77 million (US$ 1 040 000). The yield would be about 13.3 t lactose/day. Investment costs for yeast powder manufacture (100 000 l whey/day resulting in a yield of 1 800 kg/day) would be about DM 560 000 (US$ 220 000).

Whey powder for human consumption is used, for instance, in ice-creams (and possibly their imitations), yoghurts, "dairy snacks" whipped products (111) and in bakery goods and meat processing industries.

U.S. Patent 2923628 "Synthetic Milk" of 2/2/1960 by Harold L. Otto describes an imitation milk consisting of about 60-80 percent water, 5-10 percent whey proteins, 5-10 percent fat and 5-10 percent salts. The use of whey protein in infant formulae has already been mentioned.

The nutritional value of whey protein obtained by modern technology is very high. The PER and NPU 1/ values are higher than those of all other proteins except egg protein. Of special interest are the high lysine, tryptophan, threonine and sulphur-amino-acid contents which make whey protein especially valuable to supplement vegetable protein of poorer nutritional quality.

Recently USDA and USAID have tested a whey-soya mix as a supplementary food for pre-school children in developing countries and have concluded "that there is a high probability that the beverage powder will be acceptable in pre-school children feeding programmes in most parts of the developing world" (180).

1/ PER is the ratio of weight gain of a growing animal to the protein consumed. It is a measure of protein quality when determined under specific conditions; the caloric intake and the vitamin and mineral intake must be adequate and the protein must be fed at an adequate level for a specific period of time. When fed at surfeit levels, weight will no longer increase with protein intake and the ratio will fall. The PER has been used chiefly in feeding experiments on small animals. It is the simplest method of determining quality, requiring no chemical measurements, but it suffers from the possible error that weight gain may not be proportional to gain in body protein.

NPU expresses in a single index both the digestibility of the protein and its biological value (NPU = digestibility x biological value). It represents the proportion of food nitrogen retained (NPU = N retained/N intake).

Digestibility: The proportion of food nitrogen that is absorbed (39).
Biological value: The proportion of absorbed nitrogen that is retained in the body for growth and for maintenance (39).

Fish protein

The only type of fish protein which might be suitable as raw material for imitation milk would be a bland product. Most processes which have progressed beyond the laboratory stage are based on the use of organic solvents, the most important being based on isopropanol extraction or a combination of ethylene dichloride extraction and isopropanol extraction (128). However, the fish protein concentrate (FPC) obtained by solvent extraction procedures is lacking in such functional properties as solubility, water binding and holding characteristics and whippability required by the food industry. Studies are under way for the preparation of FPC to retain these characteristics of the native fish protein, e.g. in Chile, France (using enzymatic hydrolysis) (45), the U.S.A. (preparation of isolates using isoelectric precipitation techniques) (136, 137) and Sweden (83).

The PAG has established a guideline for FPC for human consumption which refers to non-traditionally preserved fishery products. The PAG defined FPC and distinguished between two types (A and B) as follows (61):

"Fish protein concentrate (FPC) is a stable product suitable for human consumption prepared from whole fish or other aquatic animals or parts thereof. Protein concentration is increased by the removal of water and, in certain cases, of oil, bones and other materials.

Type A products are essentially odourless and bland powders, usually of light colour, containing very low concentrations of lipids. Currently, only FPCs produced by isopropanol or ethylene dichloride isopropanol extraction meet type A specifications. FPCs prepared by aqueous extraction or by enzyme hydrolysis, presently only in laboratory production, may also fall into this category.

Type B products are often flavourful, have a higher content of lipid and may be presented in such various physical forms as powders, pastes or liquids according to the consumer habits in the country for which they are destined."

The composition quality characteristics of the FPCs are given in Table 26.

Table 26

COMPOSITION OF FPC TYPE A AND B ACCORDING TO PAG

	Type A	Type B (powders only 1/)
Moisture	not more than 10%	not more than 10%
Lipids	not more than 0.5%	not more than 10%
Protein	not less than 75%	not less than 60%
Total ash	not more than 15%	not more than 20%
Ash (acid-insoluble)	not more than 0.5%	not more than 0.5%
Fluorine (as F)	not more than 250 ppm	not more than 250 ppm
Available lysine	not less than 6.5% of protein	not less than 6.5% of protein

1/ No specification is attempted for other type B products.

W. Meinke, M.A. Rahman and K.F. Mattil have estimated that theoretically 65 to 75 percent of the protein of fish flesh should be recoverable as a protein isolate by using the common isoelectric precipitation technique (136).

The preparation of protein isolates (including isolates not derived from fish) involves four essential steps:

(1) solution of the protein in aqueous medium with proper pH and/or salt conditions;

(2) removal of the undissolved residue (bones, grit, scales, etc.) from the protein solution;

(3) recovery of the protein from the solution as a curd by proper pH adjustments or dilutions;

(4) purification and drying of the protein fraction.

The preliminary data presented by Meinke, Rahman and Mattil were based on experiments with fresh iced fish - golden croaker, mullet and carp - or frozen fish - hake and golden croaker. Protein solubility reached its minimum in the pH range 5.5-6.0 (14 to 21 percent of the protein of the fish remaining in solution) and increased on both the acidic and basic sides of this pH range (60 to 70 percent put in solution at pH 3-4 and 9-11, varying with the type of fish). The preliminary estimates given indicate that, for example, 50 percent of the protein of the carp could be recovered in the form of curd (solubility at pH 3 or 10, 70 percent, at pH 5.5, 20 percent. Extraction of the protein at pH 3 or 10 followed by adjusting the extracts to pH 5.5 should result in a curd containing 50 percent of the protein of the carp). The data obtained for golden croaker indicate a protein recovery of 42 and 51 percent from extractions at pH 3 and 11, respectively, followed by precipitation at pH 6.0. On a dry basis, the acid curd assayed 64.1 percent protein, 17.4 percent oil and 10.2 percent ash. The alkaline curd gave values of 73.3 percent protein, 7.2 percent oil and 3.2 percent ash. Meinke and co-writers state that, while the alkaline process was better from the standpoint of product yield, colour and odour were more pronounced with the alkaline product. They emphasize that much more effort must be directed towards the production of isolates from fish, including studies on the deoiling, deodorizing and drying of isolates while retaining functionality.

In the Chilean project (45), which is operated with technical assistance from FAO, a soluble FPC (designated PH65) is prepared from hake (U.S. patent 3.561.973). Fat is added during processing. Processing consists of (1) deboning, degutting, filetting and producing pulp, (2) washing pulp, (3) grinding pulp, (4) enzymatic hydrolysis, (5) addition of additive and hydrogenated fat and homogenization, (6) pasteurization, (7) evaporation and spray drying. Twenty thousand tons of hake are reported to yield 2 000 tons of FPC protein for human consumption containing 65 percent protein, 30 percent fats (3 percent from original fish oil), 3 percent moisture and 2 percent ash, and 1 500 t of an animal feed component with a composition of 23 percent protein, 6 percent fat, 3 percent moisture and 8 percent ash. It is reported that the PER 1/ value of the food product is 2.98 and that it can replace milk in proportions up to 15 percent without being detected. It has further been stated that, when fed for three weeks as the sole source of protein to three normal infants of 3 to 6 months of age, their weight gains were similar to infants fed on cow's milk. No economic data on the process is yet available for publication.

1/ See footnote on page 44.

A method for treating whole trash fish by enzymatic hydrolysis was developed by the Association pour l'étude de problèmes de la nutrition (AEPN) in association with the University of Nantes (45). The fish are minced and hydrolysed on board the fishing vessel and filtered to remove bones and scales. The liquid which is now a mixture of completely solubilized proteins, finely suspended particles and oil is pasteurized, cooled and stored for treatment ashore. Here the three components are separated by centrifugation. The clear liquid is spray-dried. The solid matter is resuspended in water and spray-dried. There are thus four products:

Soluble FPC (Grade 1)
Suspendible FPC (Grade 2)
Oil
Solids from the first filtration on board

From 14 000 tons of crude hydrolysate the estimated yield of fish protein concentrate is 3 000 tons in a ratio 1.3 first grade and 1.0 second grade product. The first grade product is reported to be a white powder smelling slightly of fresh fish; the second a beige powder with a frank but not disagreeable fish smell. The selling price of this product,which is intended for weaning calves, pig feeding and fish culture, is French francs 4.2/kg (May 1974). It is manufactured in a completely automated factory (CTTP) in Boulogne-sur-Mer. The composition is reported to be 3-5 percent moisture, 83-87 percent crude protein, 3-7 percent fat, 5-7 percent minerals. The solubility in water is 75-80 percent. There are plans to produce a food grade product with less than 0.2 percent fat (99).

In 1972 the PAG issued a detailed Statement No. 16 on "The Potential of Fish Protein Concentrate" which includes references to safety of FPC and to the economics of production (59). As regards safety, mention may be made of the suggested upper level for IPA (isopropyl alcohol, used for extraction) residues (5 000 ppm or "good manufacturing practice"); of the possibility that species of naturally toxic fish could be included in mixed catches and that these might unkowingly be used for FPC manufacture; and of the possibility of fish containing heavy-metal compounds, particularly in catches from inshore waters near industrialized areas.

The economics of FPC (and fish meal) production depend on large supplies of fish and on production costs (direct costs, fixed costs and value of by-products, e.g. fish oil).

With regard to the economics of FPC, para. 7.13 of PAG Statement No. 16 concludes that:

"A recent economic study, based on certain assumptions, shows that Type A FPC at a price of US¢ 25/lb would not generally be competitive with other protein supplements and the cost of production by presently known techniques is estimated at about US¢ 35/lb. It is, therefore, recommended that developing countries do not invest in FPC before they have made a careful economic analysis of alternatives in their specific situations, taking appropriate account of any over-riding political or similar considerations."

The present high prices of skim milk powder (April 1974, more than US$ 1000/t) might make edible FPC an economic proposition to replace milk, even if the fishmeal price (approximately US$ 580/t) is also rather high (i.e. the raw material price has increased considerably). That statement suggests (p.7.16) that:

"Processes now in the experimental stage or just entering the commercial production stage should be watched closely and all possible information made available to developing countries."

A Canadian firm referred to in the PAG statement expected its cost of FPC production from fresh fish to be approximately Can.¢ 25/lb, of which Can.¢ 10 was raw material cost (expected yield about 6.0-6.5 to 1), the balance being processing costs, including some marketing costs. The estimate was based on a 300-day operation. It was, however, pointed out that the experience of shore-based fishmeal operations relying on fresh fish supplies showed that 100 days operation per annum is the maximum that can normally be expected. If the target of 300 days is reduced, the cost per ton of product will go up through a proportional increase in fixed costs per ton of product, i.e. the costs which do not vary with production, e.g. labour, insurance, maintenance, management, amortisation of capital and interest. A Scandinavian company indicated an ex-factory price of about US¢ 79/kg for its FPC with 85 percent protein (fishmeal price 1972 approximately US$ 250/t, in April 1974 US$ 580/t). This was based on a 25 000 ton factory ship with ten fishing trawlers operating in the South Atlantic, enabling most of the catch to be processed into fishmeal on board the factory ship, leaving part of the fish for use as raw material for FPC for human consumption. The FPC was produced from a preserved presscake, by solvent extraction and deodorizing in a land-based factory in Sweden.

The report states that healthy Swedish children aged 4-6 months were given a formula in which milk protein was replaced by FPC and that the formula was well accepted and there were no adverse reactions. It was further stated that a method has also been developed for producing fish protein with high functionality from fresh whole fish (e.g. herring) (83). The nutritive value of FPC is considered to be high with a protein quality comparable to that of milk protein.

5.2 Oilseed Protein

- soybean protein
- groundnut protein
- cottonseed protein, and
- sunflower seed, rapeseed, coconut and sesame seed protein.

Soybean protein (32)

The soybean (Glycine maxima) contains more protein (approximately 35 percent) than most legumes, but less fat (approximately 20 percent) than most oilseeds. During the past five decades it has become the world's leading legume and oilseed crop. In 1972, production amounted to over 53 million tons; more than the total production of the next two major oilseeds together, groundnuts (almost 17 million tons) and cottonseed (24 million tons). More than 90 percent of world production comes from the U.S.A. (65 percent used mainly for animal feed); China produces 22 percent and Brazil 6.5 percent. Brazil almost quadrupled its soybean acreage from 612 000 ha in 1967 to 274 000 ha in 1972. Further important producers are the U.S.S.R., Indonesia, Mexico, Canada, Korea (DPR), Korea (Republic) and Japan (see Table 27) (41).

While soybeans have a long history as a protein foodstuff in the Orient, tofu (170), a soybean curd of China and Japan, and the Indonesian tempeh, a product made from soaked and cooked soybeans by fungal fermentation, may be quoted as examples: they have only recently been used as food in the Western World (32, 170, 196, 198). In the United States soybean processing only emerged industrially in the early 1930's and they are now the most important source of edible oil, and the soymeal is a very important source of protein for animal feeds. Their use as a food also started in the 1930's and developed slowly until recently, when the rising price of animal protein created a considerable interest in soy proteins for milk and meat substitutes. An impressive amount of research has been carried out to develop soybean proteins with functional, chemical and physical properties desired by the food industry for using soy proteins as supplements or additives in standard

Table 27

MAJOR SOYBEAN PRODUCING COUNTRIES (1972)

Country	Production 1/	Area 2/	Yield 3/
U.S.A.	34 916	18 516	18.9
China	11 570	14 295	8.1
Brazil	3 500	2 274	15.4
U.S.S.R.	540	860	6.3
Indonesia	515	685	7.5
Mexico	360	185	19.5
Canada	320	164	19.5
Korea, DPR	235	405	5.8
Korea, Republic	224	280	8.0
Japan	127	89	14.3
World Total	53 024	38 489	13.8

1/ in '000 t.

2/ in '000 ha.

3/ in 100 kg/ha.

FAO Production Yearbook, Vol. 26:1972.

food products. In addition to the use of soy proteins for their functional effects there is now a trend to employ them as major source of protein whereby the exploitation of their functional properties is likely to contribute to the development of soy-based imitation milk products. The increased competition sodium caseinate is meeting from sodium soy proteinate because of lower cost is mentioned as an example.

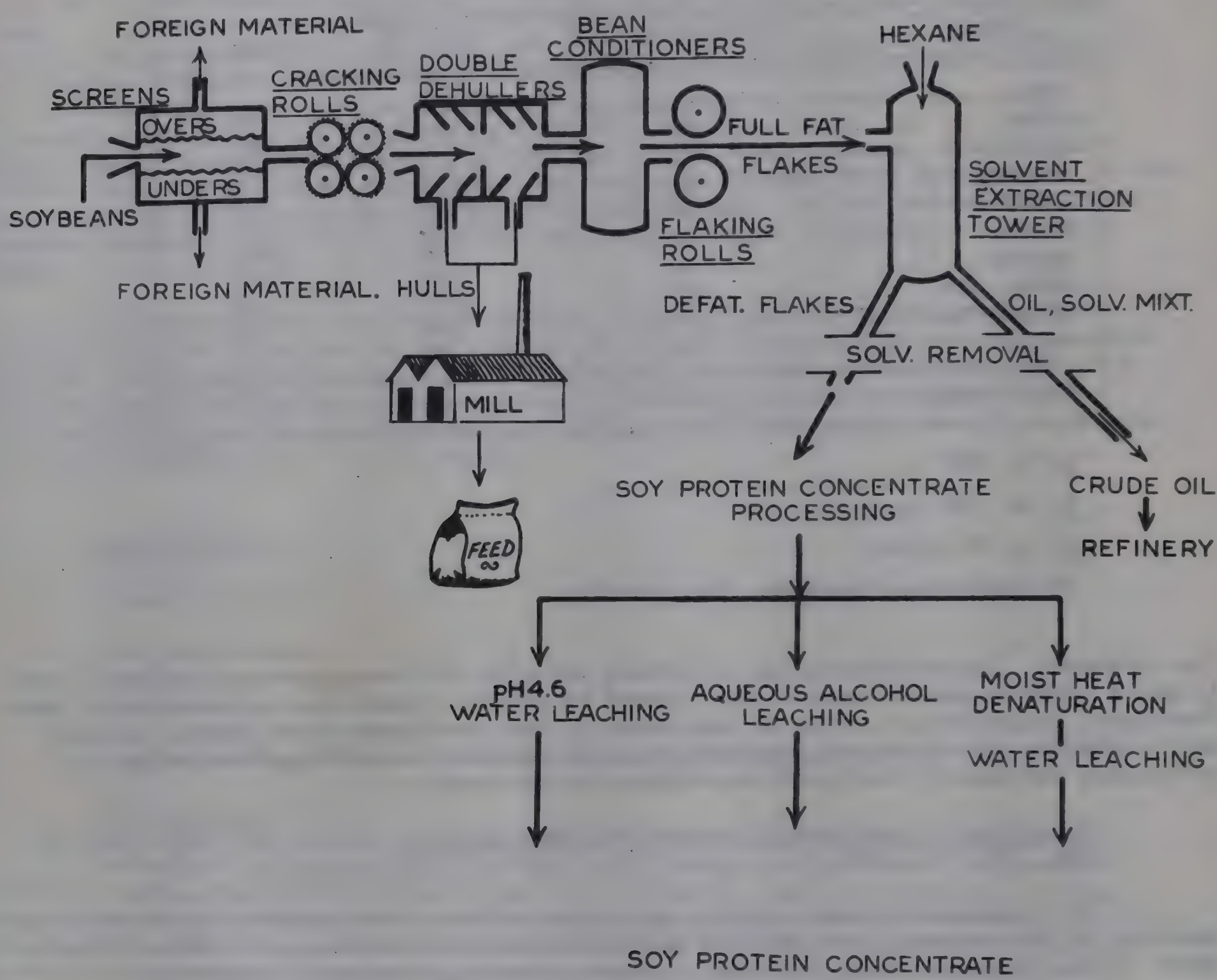
Processing of soy protein concentrates and isolates (12, 15, 26, 123, 138, 139, 196, 197, 198, 199)

For food-grade flours, flakes, grits, concentrates and isolates the selection and handling of the soybeans from the farm to the processing plant need great care. A flow-sheet giving the major steps in modern soybean processing is shown in Figure 6.

Important quality factors include grading, the removal of foreign material (deleterious weed seeds, etc.) and controlled storage to prevent deterioration and infestation by microorganisms, insects and rodents. Contamination of oilseeds and oilseed cakes or meals by microtoxins is a serious problem. However, it has been reported that in the U.S.A. there is little evidence of aflatoxin in soybeans moving in commercial channels (138).

The sound and clean beans are cracked, dehulled, tempered with moist heat, and flaked. The full-fat flakes are solvent extracted in counter current systems with hexane. The defatted flakes are dessolventized. Properly processed and handled defatted flakes must be free from pathogens and should have low standard plate counts. This is desirable in the wet processing of concentrates and isolates where microorganisms can multiply rapidly. (Sanitary plant design and hygienic manufacturing practices are essential to ensure that the raw material is suitable for the production of protein concentrates and isolates).

FIG. 6: MODERN SOYBEAN PROCESSING



Modern solvent extraction plants for soybeans in the U.S.A. have steadily increased in size during the last decade and now range in capacity from 1 000 to 1 500 t of beans per day. Proper processing (see flow sheet Fig. 6), in particular optimal heat treatment (to inactivate or destroy antinutritional factors) avoiding both underheating and overheating (and thus excessive reduction of the nutritional value of the protein) combined with intelligent and informative advertising and last, but not least, competitive prices, has created a well-established market for quite a number of soy protein products.

Based on the protein content there are three major groups of soy proteins:

(i) flakes, flours and grits, with a minimum protein content of 40 to 50 percent depending on the fat content;

(ii) concentrates, containing 70 percent protein or more on a dry basis (or 65 percent on a "as is" basis); and

(iii) isolates, which contain 90 percent or more protein on a dry basis.

A fourth group, representing very recent technological development of vegetable protein and in particular soy protein products, is the

(iv) textured (including spun) proteins.

For imitation milk products, the isolates and concentrates are the most important products.

(i) Soy flakes, flours and grits are basically concentrates of 50 percent protein. Soy flakes are flat and unground, soy grits are coarsely ground and soy flour is a finely ground product. Full-fat soy flour contains the full amount of the oil of the soybean, roughly 20 percent and about 40 percent protein. Low-fat soy flour contains up to 6 percent fat and about 50 percent protein. Defatted soy flour contains less than 1 percent fat and typically 51 percent to 52 percent protein. Food grade hexane is used for solvent extraction of the bean and moist heat treatment is used to obtain optimum flavour and palatability and to inactivate or destroy antibiological factors (e.g. antitrypsin factor and hamagglutinins, saponins and antivitamin factors). However, care must be taken to avoid excessive losses of lysine.

(ii) Soy protein concentrates are produced from defatted soy flakes. They are obtained by leaching out oligosaccharides, minerals and other soluble constituents using acidified water (pH 4.6) or aqueous alcohol (60-80 percent). Alternatively, the defatted material is denatured by means of moist heat followed by extraction with water (see Fig. 6). The physical properties of the concentrates will differ with the method of preparation. Concentrates prepared by acid leaching and neutralization in the absence of heat treatment will have a higher content of soluble protein (Table 28, product B) than concentrates obtained by heat and alcohol treatment (Table 28, products A and C). The yield of dry concentrate has been reported to be 60 to 70 percent defatted flake weight. Concentrates have a clean bland flavour and very good keeping qualities. They are used in infant and dietary foods and also in calf-milk replacers.

(iii) Soy protein isolate is derived from defatted soy flakes or flours by removing the water-insoluble polysaccharides, the oligosaccharides and other low-molecular weight components that are separated in making protein concentrates. The defatted flakes or flours which have received a minimum of moist heat treatment are extracted with an aqueous alkaline

medium (pH 7 to 8.5). The insoluble residue (containing the water-insoluble polysaccharides) is separated. The clarified extract which contains the bulk of the protein and the sugars is adjusted to pH 4.5 with food grade acid. This treatment precipitates the proteins which are removed by centrifugation, washed, neutralized and dried. This procedure results in proteinates which are water dispersable. Isoelectric proteins, which are insoluble in water, are obtained when the protein is not neutralized before drying. An approximate analysis of some commercial isolates is given in Table 28. All have a low crude fibre content which is due to good protein extract clarification and curd separation. Isolates A and B are in the neutralized form, isolates C and D in the isoelectric form. The yield has been reported to vary from about 30 to 40 percent of the defatted flake weight. The compositional characteristics of commercial soyprotein concentrates and isolates are given in Table 28.

Table 28

APPROXIMATE ANALYSES OF COMMERCIAL SOY PROTEIN CONCENTRATES AND ISOLATES

Analysis, percentage	Concentrates			Isolates			
	A	B	C	A	B	C	D
Moisture	6.7	5.2	3.1	4.7	6.4	7.6	3.7
Protein	66.2	67.3	69.6	92.8	92.2	92.9	94.7
Protein (dry basis)	70.9	71.1	72.2	97.4	98.7	100.0	98.4
Fat	0.3	0.3	1.2	-	-	-	-
Crude fibre	3.5	3.4	4.4	0.2	0.1	0.1	0.2
Ash	5.6	4.8	3.7	3.8	3.5	2.0	2.7
Nitrogen solubility index	5.0	69.0	3.0	85.0	95.0	-	-
pH (1:10 aqueous dispersion)	6.9	6.6	6.9	7.1	6.8	5.2	5.5

Meyer, E.N.W., 1971, J. Am. Oil Chemists Society, 48, (9), 484-488.

Isolates are used by the food industry because of their many valuable properties such as emulsifying, stabilizing, fat and water binding, thickening, texture forming, etc. The major area of utilization in the United States is in communited meat products and textured foods. Other uses include infant food formulae and products such as coffee whiteners, whipped toppings, frozen desserts and beverage powders.

(iv) Textured soy proteins. The basic process of preparing spun fibres was described by Boyer (U.S. patent, 2,682,466) (160, 202). Fibres are produced by extruding an alkaline dispersion of soy isolates through spinnerettes into a coagulating bath. The resulting filaments or fibres are washed and formed into various products such as chicken, beef, ham, etc. with the aid of binding agents, food flavours, colours and other ingredients.

Another type of textured soy protein is made by thermoplastic extrusion (164). The process employs the less expensive soy flours instead of isolated soy protein. In this process a mixture of soy flour, water, flavouring and colouring agents is fed into a thermoplastic extruder where it is subjected to heat and pressure for a predetermined time. Depending upon the condition of the starting material and other factors, the extruded particles may either be compacted or expanded.

R.W. Fisher, President of Soypro International, describes the two types of products as follows (69):

"1. Extruded, expanded, ... which have been given a structure of small air-spaces in an irregular matrix of plasticized proteinous material ... made in various densities and with a variety of flavours and colours incorporated.

2. Extruded, compacted ... which have been given a plasticized structure without the 'puffed' or 'expanded' characteristic."

A protein beverage called "Vitasoy" containing about 2.5 percent soy protein has been reported as competing successfully in the soft drink market in Hong-Kong (148). A food blend called CSM (corn-soya-milk) containing gelatinized corn meal (63.8 percent), non-fat dry milk solids (5.0 percent), soy oil (5.0 percent), minerals and vitamins (2.0 percent) in addition to defatted soy flour (24.0 percent) has been distributed in the past few years to millions of children in more than 100 countries as a donation of the U.S. Government (approximately 500 000 tons between September 1966 and October 1970) (5, 27). It is an interesting example for combining protein sources for supplementary purposes to arrive at a product corresponding to the nutritive qualities required.

According to USDA estimates, the production of soy protein foods in the United States in 1970 was about 250 000 tons of flour and grits, 16 000 tons of concentrates, 11 000 tons of isolates and 14 000 tons of textured items (75).

Groundnut protein (31)

The kernel of the groundnut (*Arachis hypogaea L.*) contains more fat than the soybean (about 45-50 percent) but less protein (about 27 percent). Major groundnut producing countries are India, China, Nigeria and the United States of America. The total estimated world production in 1972 was 16.9 million tons unshelled weight (see Table 29) (41). India, China and the United States retain all or most of their groundnut production for domestic use whereas Nigeria and Senegal export large quantities.

In the United States, more than 73 percent of the domestic production was utilized for direct consumption (3.2 kg per caput per annum, 1968-70), while India used only 7 percent. Large quantities of groundnuts are consumed either raw or after a simple type of processing such as roasting and salting. Another form of processing is hand pressing of the kernels to produce oil and a crude flour (for soups and stews), the latter being practised in Nigeria and Ghana. Peanut butter, a paste made from ground whole nuts, accounts for the high consumption in the United States and is also known in other countries such as India. Groundnut milk and curd are popular in some parts of China.

In India a milklike beverage called "Miltone" (formerly "Lactone") is produced in the State Milk Plant in Bangalore and by a private firm in Bombay under the brand name of "Milpro". The product was developed by the Central Food Technological Research Institute,

Mysore, under a research grant from the National Institute of Health, U.S.A. (see also below). UNICEF is assisting in scaling up the production. The purpose is to use groundnut protein for "toning" 1/ or extending the milk supply as in the case of toning (25, 197).

Table 29

MAJOR GROUNDNUT PRODUCING COUNTRIES (1972)

Country	Production 1/	Area 2/	Yield 3/
India	4 500	6 900	6.5
China	2 650	2 290	11.6
Nigeria	1 233	1 855	6.7
U.S.A.	1 485	602	24.7
Brazil	850	650	13.1
Senegal	650	950	6.8
Burma	520	650	8.0
Indonesia	455	356	12.8
South Africa	420	351	12.0
Sudan	370	420	8.9
Niger	270	400	6.8
Argentina	252	294	8.6
Thailand	227	140	16.2
Uganda	215	250	8.6
Cameroun	215	210	10.2
Zaire	180	270	6.7
Mali	130	250	5.2
World Total	16 887	19 665	8.6

1/ In '000 t (groundnuts in shell).

2/ In '000 ha.

3/ In 100 kg/ha.

FAO Production Yearbook, Vol. 26:1972.

Aflatoxin. Before describing the edible groundnut protein products, mention should be made of the potential danger to the consumer of aflatoxin contaminated groundnuts and groundnut products. This problem, which is currently the subject of intensive research, might exist to a lesser degree with other oilseeds depending on the conditions of handling and storage. The toxins which are produced by the fungus *Aspergillus flavus* were identified in 1960 in groundnut meal. Four closely related compounds were identified, later called aflatoxins B_1, B_2, G_1 and G_2 which were found to have caused the deaths of some 100 000 turkey poults in Britain. The toxins are known to produce liver disorders in animals. The poultry had been given feed containing contaminated groundnut meal. In cows and sheep these mycotoxins are partially metabolized to form another series of toxins, designated aflatoxin M. Cows fed on a feedstuff containg aflatoxin excrete a certain percentage of the ingested aflatoxin as aflatoxin M in the milk.

1/ "Toned milk" and "double-toned milk" are products made by mixing buffalo's or cow's milk with (reconstituted) skim milk to reduce the fat content while maintaining the protein content of the milk. (In India toned milk contains 3.0 percent fat and 8.5 percent non-fat solids, double-toned milk 1.5 percent fat and 9 percent non-fat solids. These products should not contain any other constituents except those derived from milk (Prevention of Food Adulteration Rules, 1959, Ministry of Health, 1962)).

The FAO Intergovernmental Group on Oilseeds, Oils and Fats discussed the topic at its seventh session in February 1973 in Rome (46) and the African Groundnut Council also discussed this at a symposium on "Problems of Storage and Handling of Groundnuts and other Food Grains and Animal Feeds", held in Kaduna, Nigeria, from 2 to 6 April 1973. The part of the report concerned with aflatoxin reads as follows (47):

> "Studies on the effect of aflatoxin on farm animals is by no means complete. This makes universal agreement on toxicity levels in animal feeds extremely difficult, if not impossible, at present. However, there is a building body of information in this field. Also, animals differ drastically in their response to feeding on contaminated meal and vary from susceptible to very resistant species.
>
> There is no evidence that aflatoxin affects man in the same manner it does experimental laboratory animals. The circumstantial evidence existing cannot be attributed to one commodity or another due to the universal distribution of aflatoxin. The Protein Advisory Group of the FAO/WHO in Geneva gives the level of 30 µg/kg for feedstuffs meant for human consumtpion; this is understandable although very stringent indeed.
>
> It is pertinent at this juncture to emphasize that there is no direct evidence available as to the effect of aflatoxin on man or the level at which toxicity becomes apparent."

The growth conditions for Aspergillus flavus and the conditions for aflatoxin production include an ambient temperature of 10–45°C and a relative humidity of at least 75 percent. At this humidity the equilibrium moisture content of groundnuts is 9 percent and of groundnut meal or cake 16 percent.

Control, preventive measures and detoxification. Drying of harvested groundnuts should take place quickly after harvesting to reduce the moisture cortent of the nuts below the critical 9 percent level.

Other factors leading to high contamination are shell damage and kernel splitting which can be caused by insects, poor harvesting practices and drought. As regards storage and transport, care has also to be taken to avoid exposure of the kernels and the meal to damp conditions.

Various procedures for detoxification of aflatoxin contaminated groundnuts and groundnut products have been tried (90). It appears, however, that the only process in use is the chemical inactivation of aflatoxins during aqueous processing of mold-infested nuts with oxidizing reagents. The Central Food Technological Research Institute (Mysore) has developed a process which involves suspension of groundnut meal in an alkaline medium, mixing it with an oxidizing agent such as hydrogen peroxide, and heating the mixture. The material is then cooled and the excess oxidizing agent is removed. The product is then dried and packed (151). K.C. Rhee, K.F. Mattil and C.M. Cater have reported reduction of aflatoxin in groundnut concentrates and isolates below 25 ppb from about 1 000 ppb with hydrogen peroxide at concentrations of 0.5 percent. Sodium hypochlorite at 2.0 percent concentration completely inactivated aflatoxins in these products (163). The best solution to the aflatoxin problem would be to prevent the development of fungi producing toxic substances in the oilseeds. The member states of the African Groundnut Council hold the view that

> "the best method is in the control methods, which include planting varieties suited to various ecological zones, harvesting at maturity, drying to safe moisture content before storage and storing insect-free intact kernels in disinfested bags in hygienic stores which are water, rodent and bird proof and gas tight. Comprehensive programmes for educating the farmer towards

wholesome crop production are also being practised. This is believed to be an important factor in minimizing mycotoxin infection. Discarding damaged pods, broken and blemished kernels would be an effective way of producing a wholesome crop" (47).

Another preventive method is to fumigate the crop after harvesting with a combination of ammonia and phosphine or ethylene di-bromide and methyl bromide. Fumigation can be carried out in the field under polythene sheets, after which the oilseeds are dried as soon as weather conditions are favourable (46).

A control measure which is neither preventive nor a detoxification is the elimination of infested and therefore potentially contaminated seeds. Physical characteristics of the kernels, i.e. size, shape and colour, can be used to sort out the infested material either by careful hand-picking by trained workers or by electronic colour sorting.

Groundnut protein products. Removal of oil is an essential step in the preparation of most protein products. Groundnuts are normally shelled before milling to improve oil yields. Shelling the nuts either by hand (pestle and mortar, hand machines) or by mechanically driven machines, is followed by cleaning, roasting and blanching the kernels (removal of testa (skin) and hearts (germs): the testa contains goitrogens and protease inhibitors, and the hearts contain some saponins), removal of defective and mould infested kernels by hand-picking or colour sorting, and breaking and cooking the kernels to condition them for the extraction of the oil by pressing or solvent extraction. Pressing is done by means of wooden or metal hand presses in small-scale processes, or by continuous screw presses, in large enterprises.

Solvent extraction is usually done on a continuous basis, but there are also batch type solvent units for small oilseed mills. The solvent used is food grade hexane. After low-pressure expelling, the material is flaked to allow the solvent to reach the oil in the cells. The oil is then extracted in a continuous countercurrent system (see processing of soybeans).

Groundnut protein concentrates and isolates can either be produced by extracting proteins from defatted meal after oil extraction or by simultaneous recovery of proteins and oil using centrifugal separation in an aqueous medium. It has been claimed that aqueous extraction offers a number of advantages, such as safer operations owing to the absence of volatile solvents; one-step separation of proteins and oil; the production of a variety of products with a wide range of functional characteristics; and the utilization of certain oxidizing or alkaline chemicals for inactivation of aflatoxins (163).

(i) Protein Concentrates

An oil-free or low-oil protein concentrate contains 45 to 55 percent protein. The (pilot scale) production of protein concentrates by aqueous extraction as developed at Texas A & M University comprises the following steps (see Fig. 7); comminuted cleaned groundnut cotyledons are dispersed in water (1:6 w/v) in a jacketed stainless steel mixing tank with a propeller-type mixing attachment. By adding concentrated hydrochloric acid the pH of the continuously stirred dispersion is brought to 4.0. While maintaining the dispersion at pH 4.0, it is rapidly heated to 60–65°C. After one hour of extraction under these conditions most of the solids are removed by screening or by a continuous clarifying centrifuge. Solids may be spray dried "as is" for an isoelectric protein concentrate or, after neutralization with alkali, for various proteinates. The solids may be washed prior to these procedures for products of greater purity. The resultant liquid extracts and washings are combined in a mixing tank. By means of an automatic desludging 3-phase centrifuge the oil is separated from other constitutents

FIG. 7: SIMPLIFIED FLOW DIAGRAM FOR THE MANUFACTURE OF GROUNDNUT PROTEIN CONCENTRATE USING AQUEOUS EXTRACTION, AS DESCRIBED BY K.C.RHEE, K.F.MATTIL, AND C.M.CATER.

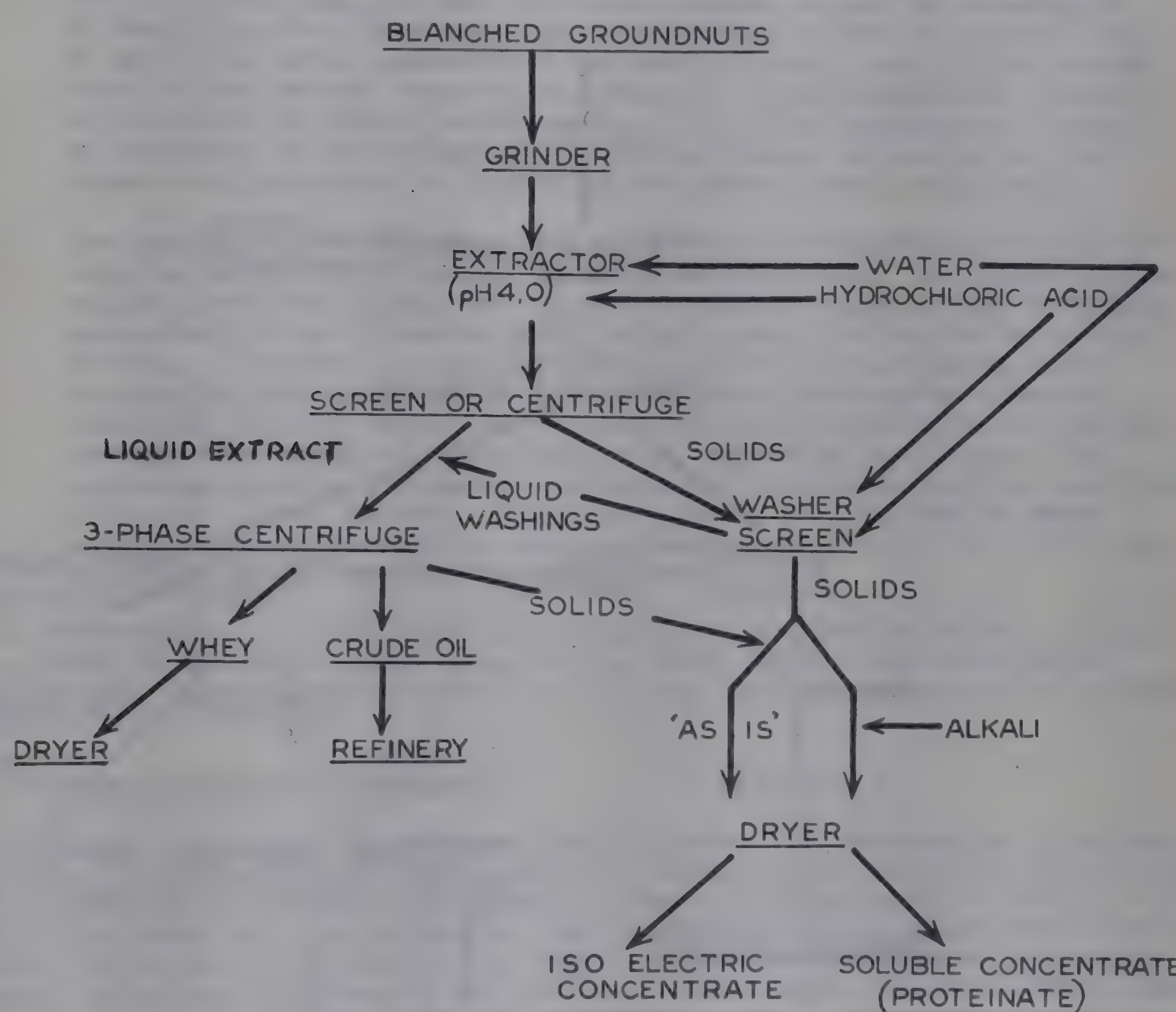
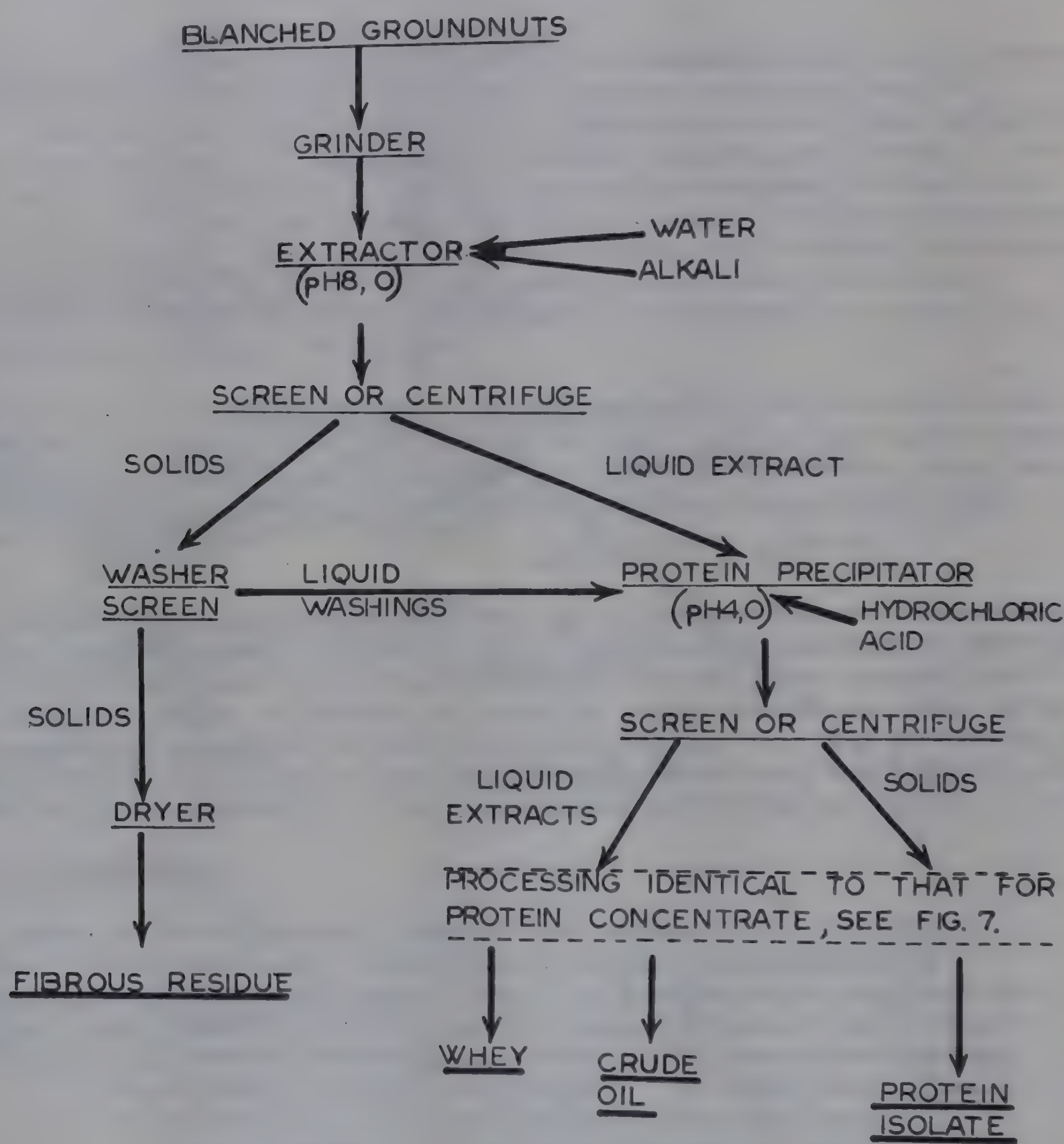


FIG. 8: SIMPLIFIED FLOW DIAGRAM FOR THE MANUFACTURE OF GROUNDNUT PROTEIN ISOLATE USING AQUEOUS EXTRACTION, AS DESCRIBED BY K.C. RHEE, K.F. MATTIL, AND C.M. CATER.



in the liquid. The crude oil may be refined to produce edible groundnut oil. The liquid whey may be concentrated and spray dried to recover groundnut whey solids. In the trials carried out at Texas A & M University 92 percent of the proteins of the starting material and 89 percent of the oil were recovered (163).

(ii) Protein Isolates

The process described by Rhee, Mattil and Cater (163) for production of groundnut protein isolates comprises the following steps (see Fig. 8): the comminuted blanched groundnuts are dispersed in water, the dispersion is heated to 60-65°C and adjusted to pH 8.0 by adding a 40 percent sodium hydrochloride solution. Under these conditions more than 96 percent of the protein in the groundnuts is reported to be solubilized. After an hour of extraction, residual solids are removed either by screening or by centrifugation. The proteins in the liquid extract are precipitated at pH 4.0 by adding concentrated hydrochloric acid. Most of the protein curd is then removed either by screening or by centrifugation. The oil is separated by 3-phase centrifugation. The final products are treated as described for the concentrates. In the trials carried out at the Texas A & M University 89 percent of the proteins were recovered.

The aqueous processing allows the inactivation of aflatoxins by means of alkaline or oxidizing agents, which are water-soluble. The above authors suggest that these agents can be used at various stages of the extraction processes: at the extraction step, protein precipitation step or during washing. A process for the commercial production of groundnut protein isolate has been developed by the Central Food Technological Research Institute, Mysore, India. It is based on alkaline extraction of low fat groundnut meal and acid precipitation of protein in the filtered (to remove non-protein substances) and hydrogen peroxide treated (to inactivate aflatoxin) liquid extract. The protein slurry is clarified to remove soluble carbohydrates; it is then neutralized and dried. The isolate has a protein content of 90-95 percent.

In the preparation of "Miltone" and "Milpro" the wet protein isolate is used, i.e. the product at the stage before spray drying, which results in a reduction of processing costs. Miltone has also been found suitable for the preparation of an imitation yoghurt (25).

Cottonseed protein (42, 132)

The annual production of cottonseed, which together with soybeans and groundnuts comprises about 90 percent of the major oilseed production of approximately 100 million t, amounted to 24 million t in 1972. Its protein content of approximately 20 percent is lower than that of the other two major oilseeds. Ten countries account for more than 80 percent of the world production of cottonseed, the largest being the United States, producing approximately 20 percent, followed by the U.S.S.R., China, India, Pakistan, Brazil, Egypt, Turkey, Mexico and the Sudan (see Table 30) (41).

In spite of the work done by the Southern Regional Research Laboratory of the U.S.A., by the Institute of Nutrition of Central America and Panama (INCAP) in Central and South American countries over more than ten years; by the Regional Research Laboratory, Hyderabad, India; by a few North American companies and one Italian company; the total production of edible cottonseed flour compared with the total production of cottonseed cake is very small. It is used essentially in Central America for the formulation of Incaparina, a mixture of corn meal with about 38 percent cottonseed flour, plus some brewers' yeast, milk powder and vitamins, and was developed by INCAP.

Table 30

MAJOR COTTONSEED PRODUCING COUNTRIES (1972)

Country	Production 1/	Area 2/	Yield 3/
U.S.A.	5 041	5 324	9.5
U.S.S.R.	4 850	2 730	18.0
China	2 819	4 502	6.3
India	2 254	7 972	2.9
Pakistan	1 402	2 025	7.0
Brazil	1 277	2 631	4.9
Egypt	905	652	14.0
Turkey	826	660	12.5
Mexico	667	500	13.3
Sudan	447	505	8.8
Iran	370	340	10.4
Syrian Arab Republic	269	250	10.4
Greece	252	165	15.3
Colombia	243	240	10.0
World Total	24 107	33 909	7.1

1/ In '000 t.

2/ In '000 ha.

3/ In 100 kg/ha.

FAO Production Yearbook, Vol. 26:1972.

Harvesting and practices before oil milling and flour production. Harvesting should take place rapidly after the majority of the green bolls of cotton have ripened and opened by hand picking, machine picking, hand pulling, machine stripping, or a combination of these techniques. In the gin the cotton fibres are removed from the seed by means of circular gin saws or rollers. The ginned seeds retain a covering of short fibres, the "lint". In the processing mills the seeds have to be stored under dry conditions to avoid danger of heating (for safe storage the moisture content of the seed should be less than 12 percent). The percentage of free fatty acids and the amount of colour in the oil increases during improper seed storage. The first step in processing is the removal of foreign matter by a combination of magnets, screens and aspirating chambers. Then the seeds pass the linters. (Lint may be used for upholstery, manufacture of rayon, etc.). Following delinting the seeds are decorticated, i.e. run through cutters which cut the fibrous seed husk into several fragments, and through separators which remove the hull and lint particles from the seed kernels. The oil milling processes, hydraulic (now obsolete) screw press, pre-press solvent processing and direct hexane solvent extraction are similar to the ones summarized for soybean oil milling.

Gossypol, a toxic polyphenol, is the principal pigment of glanded cottonseed. It is located in the pigment glands of the seeds. The glands represent about two to three percent of the weight of the kernel and contain 35-45 percent gossypol (185). They are ruptured during the preparatory operations prior to solvent extraction. Gossypol is responsible for nearly all oil colour problems and plays an important role in decreasing the protein quality of cottonseed meal by binding lysine and thus lowering the amount of available lysine. Free gossypol is toxic to monogastric animals. Work on breeding for glandless and therefore gossypol-free cottonseed has been in progress for some time in the U.S.A., Brazil, Africa, India and Central America. Unless, however, the farmer is assured that the oil mill will pay more for glandless seed, that the protection against pests is not more difficult, and that the yields will be at least the same as those received from traditional seeds, it will be very difficult to convince him to use a new seed. While there are claims by breeders to have a glandless seed that will equal or better the yields and quality of cotton now being produced, there is as yet no indication that a major breakthrough as regard the use of glandless seeds has occurred.

The only process of significance which produces low-gossipol flour from glanded cottonseed appears to be the liquid cyclone process developed by the USDA's Southern Regional Research Laboratory, New Orleans (203). The first commercial cottonseed flour mill using the USDA's liquid cyclone process is the Plains Cooperative Oil Mill, Lubbock, Texas, which is reported to have been designed to produce 25 tons of cottonseed per 24 hour-day, the food grade flour to contain 65 percent protein. The liquid cyclones that fractionate protein flour, gossipol and coarse particles are the key to the process.

The process, adapted for commercial size operation, comprises the following major steps (see Fig. 9).

Delinted cottonseeds are screw-conveyed to dehullers. The kernels are separated by screening and air-culling and dried in a gas-fired air dryer (160°F) to a moisture level below 1 percent. High moistures - over 3 percent - rupture the pigment glands which prevents clean separation in the liquid cyclones. The dried kernels are delivered pneumatically to the pinmills. About half the kernel's protein is recoverable by pin-mill grinding to 325 mesh. (Finer grinding - as with flaking mills - would rupture the pigment glands that average 100 microns). The milled kernels are transferred into the explosion-proof processing building and mixed with hexane. Several safety arrangements have been installed such purge fans, vapour barriers, etc. The slurry (20-22 percent solids) is agitated and fed to the liquid cyclones which consist of two sets of dual-operating cyclones (primary and secondary) thus increasing throughput and gaining better separation of the overflow (high in protein and essentially free of gossypol) from the underflow (containing hulls, coarse particles and most of the pigment glands). After the overflow fraction has been disolventized and dried, it turns light in colour and contains about 65 percent protein.

The cyclones' underflows are filtered. The filtered "cake" is washed free from cottonseed oil with hexane, desolventized and conveyed to the cattle feed mill. The oil-hexane filtrate is evaporated. The solvent is returned to the tank for re-use, the oil, representing 33-35 percent of the kernel, is pumped back to the refinery.

<u>Sunflower seed, rapeseed, coconut and sesame seed protein</u>

Other oilseeds of interest as potential protein sources are coconut, sesame and sunflower seed, also used directly for human consumption, and rapeseed. Sunflower and rapeseed rank fourth and fifth respectively in world production of oilseed crops (see Table 32).

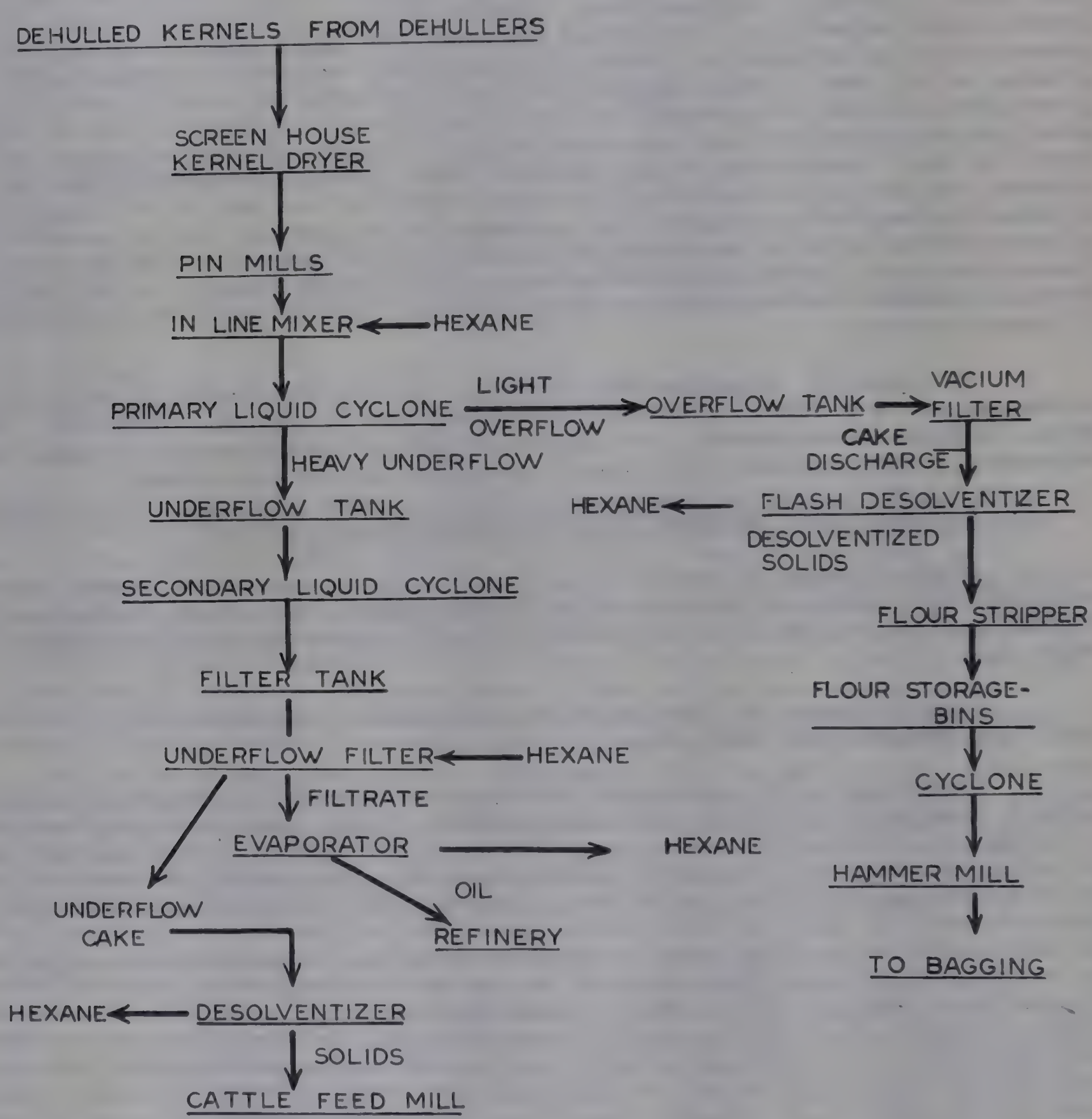
Major producers of coconuts are the Philippines, Indonesia, India, Sri Lanka, Mexico and Thailand (see Table 31).

Traditionally, the coconut is dried to obtain copra (the dehydrated coconut kernel), from which the oil is extracted by means of screw pressing or prepress solvent extraction or a combination of both methods. Using the residual copra cake as a source of protein for food has a number of disadvantages (33, 35, 72), such as discoloration and denaturation of protein (in the case of screw press cake), and degradation due to microbial spoilage which may easily occur under tropical conditions which would prevent the utilization of the press cake for human consumption. Wet-coconut process to extract protein and oil from the fresh coconuts (as opposed to copra) which would avoid these disadvantages have received considerable attention in recent years. There are a number of wet-processes all of which have two common features, the production of an emulsion (all processes use the fact that coconut contains already an emulsification system: oil water and protein as surface-active agent) and the breaking of this emulsion in order to recover the oil and the protein (see also the method described above for groundnut processing).

D.A.V. Dendy and W.H. Timmins (33) from the Tropical Products Institute (TPI), London, recently reported about a process devised by the TPI whereby oil, meal and isolates can be obtained or a coconut milk from the emulsion after removal of the oil by centrifugation.

FIG. 9: SIMPLIFIED FLOW DIAGRAM FOR THE MANUFACTURE OF COTTONSEED PROTEIN

LIQUID CYCLONE PROCESS AS DESCRIBED BY J.V. ZIEMBA, AND J.E. HERZER.



Major producers of sunflower seed are the U.S.S.R. (more than half of world production), Argentina, Romania, Turkey, Bulgaria, U.S.A., Yugoslavia and Spain (see Table 31).

Much interest has been directed to the potential use of sunflower seed in human food, but, so far as is known, there are no commercial protein concentrates or isolates available except for some crude solvent-extracted meals. G. Agren and A. Eklund (1972) prepared protein concentrates from sunflower seeds by different techniques and tested one type of concentrate as a supplement to cereal-based diets for pre-school children. The supplemented diets were reported to be palatable, well-tolerated and nutritious (1). The preparation of protein isolates has been reported by F.W. Sosulski and A. Bakal (172) and S. Gheyasuddin *et al.* (78). It has been reported that sunflower seed is essentially free from nutritionally undesirable material (153, 168, 171).

Major producers of rapeseed are China, India, Canada, France, Poland, Sweden, Pakistan, Germany (Federal Republic), and Germany (Democratic Republic) (see Table 31). With rapeseed the problem is that it contains thioglucosides which decompose by chemical or enzymatic reactions, yielding undesirable products similar to mustard oils (168). Another sulphur-containing compound, goitrin, is also present in rapeseed. These sulphur-containing compounds are the limiting factor in the use of rapeseed meal as a protein source for animal feed or human food. Research for varieties with low thioglucoside content and on the detoxification of rapeseed meal is underway in particular in Canada, India and Sweden. A new process for rapeseed concentrate for human consumption has been developed in Sweden by Karlshamns Oljefabriker in cooperation with Alfa-Laval A.B., Tumba, which is reported to produce a non-toxic, bland, light-coloured product with 65 percent protein, less than 1 percent fat, 26 percent carbohydrates, 7 percent crude fibre, 5 percent phytin, 7 percent total ash and 0.15 percent glucosinolates on a dry basis. R.O. Ohlson reports that the functional properties are comparable to those of soybean protein concentrate (6, 153).

Major producers of sesame seed are India, China, Sudan, Mexico, Venezuela and Burma (see Table 31). The PAG has issued a guideline (No. 14) on the preparation of edible sesame flour (63).

Table 31

MAJOR SUNFLOWER SEED, RAPESEED, SESAME SEED AND COCONUT PRODUCING COUNTRIES, 1972
('000 tons)

Sunflower seed		Rapeseed		Sesame seed		Coconuts 1/	
U.S.S.R.	5 030	China	1 702	India	375	Philippines	8 000
Argentina	828	India	1 451	China	353	Indonesia	5 300
Romania	800	Canada	1 300	Sudan	260	India	4 345
Turkey	570	France	722	Mexico	160	Sri Lanka	1 890
Bulgaria	494	Poland	450	Venezuela	132	Mexico	1 300
U.S.A.	350	Sweden	325	Burma	115	Thailand	1 000
Yugoslavia	277	Pakistan	301				
Spain	243	Germany, Fed.Rep.	249				
		Germany, Dem.Rep.	220				
World	9 450	World	6 904	World	1 930	World	27 930

1/ FAO estimates.

FAO Production Yearbook, Vol. 26:1972.

Development of world oilseed production

A comparison of the production figures 1948–52 and 1961–65 shows that the production of soybeans and of sunflower seed increased by approximately 100 percent. The production of groundnuts, cottonseed and rapeseed increased by approximately 50 percent (see Table 32) (40, 41).

Taking the period 1961–65 as a basis, soybean production increased by another 50 percent during the following years, reaching more than 53 million tons in 1972, and the production of cottonseed by another 25 percent reaching 24 million tons in 1972. The production of rapeseed increased by more than 50 percent to almost 7 million tons. Acreages and yields also increased significantly. Taking into account average protein contents of 36 percent for soybeans, 21 percent for cottonseed, 20 percent for groundnuts, 20 percent for rapeseed, 18 percent for sunflower seed, and making allowances for oilseeds not crushed, FAO estimates of available protein in 1972 (in million tons) are as follows (49):

soybean cake	14.4
cottonseed cake	3.3
groundnut cake	2.4
sunflower seed cake	1.5
rapeseed cake	1.4
other oilseed cake	1.3
Total	24.3

As a comparison, world (cow) milk production in 1972 amounted to 375 million tons (excluding milk sucked by calves), or 415 million tons including buffalo, sheep and goat milk, i.e. approximately 15 million tons of milk protein, the greater part of which is used for human consumption, whereas only a very minor part of the protein-rich products manufactured from cottonseed, groundnuts and soybeans are food-grade products.

Prices for oilseed protein and vegetable oils

While the fat component represents a major share of the ingredient cost for milk products and their substitutes, the cost of the protein component is also important, particularly in products with a high protein content.

Table 33 indicates that the price for oil cakes or meals showed a slight upward trend between 1965 and 1971, that the prices increased considerably in 1972, reaching unprecedented levels in mid-1973 (48, 154). This is mainly thought to be due to short-term factors. As expected, these prices fell to more normal levels in late 1973 and 1974. However, in the longer run, prices are likely to resume their upward trend.

The price of the isolates depends to a large extent on the scale of production and the degree of processing (Table 34). D.M. Beloglavec (14) states that

> "The scale of production is the most important cost factor, especially as the rather substantial research cost can be easily spread only in large-scale production. Research costs will level off only when most technical and nutritional problems are solved. The fixed and capital cost tends to diminish with increased output. Therefore, large-scale production might substantially reduce prices in the future. Current prices can be only indicative of current production costs at the current production level" and

> "The equipment costs depend not only on the capacity, but change considerably with production techniques, too. The equipment costs for production of 50 tons/month of soybean isolates were about US$ 1 million in 1971. The investments for a plant producing about 5 000 tons of concentrates require US$ 1 095 000 of which about US$ 370 000 are expenditures for processing equipment.

Table 32

PRODUCTION OF MAJOR OILSEEDS, WORLD TOTAL

	Soybeans			Groundnuts (in shell)			Cotton seed			Sesame seed			Sunflower seed			Rapeseed		
	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield
1948–52	15 952	16 024	10.0	9 705	11 877	8.2	13 941	30 962	4.5	1 777	5 101	3.5	3 863	6 294	6.1	2 817	5 172	5.4
1961–65	32 468	28 286	11.5	15 439	17 588	8.8	19 904	33 012	6.0	1 671	5 416	3.0	7 337	7 021	10.5	4 286	7 881	5.4
1967	40 640	32 969	12.3	17 365	18 888	9.2	19 302	30 994	6.2	1 736	6 002	2.9	9 983	3 832	12.7	5 370	8 477	6.3
1968	43 762	33 650	13.0	15 707	18 363	8.6	21 133	31 505	6.7	1 644	5 623	2.9	9 894	7 746	12.8	5 728	8 575	6.7
1969	45 008	34 055	13.2	16 714	18 374	9.1	21 092	32 700	6.5	1 792	5 730	3.1	9 855	7 963	12.4	4 993	7 933	6.3
1970	46 340	35 767	13.0	17 685	18 860	9.4	21 389	32 967	6.5	2 127	6 250	3.4	9 885	8 419	11.7	6 682	9 474	7.1
1971	48 291	36 182	13.3	18 480	18 840	9.8	21 976	33 093	6.6	2 098	6 395	3.3	9 694	8 591	11.3	7 880	10 322	7.6
1972	53 024	38 489	13.8	16 887	19 665	8.6	24 107	33 909	7.1	1 930	5 820	3.3	9 450	8 790	10.8	6 904	10 180	6.8

Production in '000 tons.

Area in '000 ha.

Yield in 100 kg/ha.

FAO Production Yearbook, Vol. 25, 1971, and Vol. 26, 1972.

Table 33

INTERNATIONAL MARKET PRICES FOR OIL CAKES OR MEALS FROM SOYBEANS, GROUNDNUTS, COTTON, RAPESEED, SUNFLOWER SEED, COPRA AND FISH

(US$/metric ton)

Year	Soybean	Groundnut	Cotton	Rapeseed	Sunflower	Fish
1965	97	106	90		84	195
1966	107	103	93		85	170
1967	99	100	90		82	132
1968	98	97	85	66	79	130
1969	95	100	82	66	80	179
1970	104	109	98	84	88	202
1971	105	105	93	71	88	178
1972	124	117	99	91	100	243
Jan/Dec. '73	302 1/	266 2/	225 3/	178 4/	217 5/	542 6/
May 1973	364	287	214	185	231	578
May 1974	157	152	150	153	127	359

1/ U.S. 44 percent, cif Rotterdam.

2/ Any origin, 50 percent, cif Hamburg.

3/ Turkish/S. American, 45 percent, cif Hamburg.

4/ 34 percent, fob ex-mill Hamburg, prompt shipment.

5/ Argentina/Uruguay, 38 percent, cif Rotterdam.

6/ 65 percent, c&f Hamburg.

FAO, 1973, Committee on Commodity Problems, Intergov. Group on Oilseeds, Oils and Fats, Working Paper CCP:OF/ST 73/CRS 2 Feb. 1973: figures for 1965-71.

Oil World Weekly, 18/XVII, May 3, 1974: figures for 1973 and 1974.

Manufacturing costs are primarily a function of scale. For example, for isolated soy proteins (28-30 percent yield) they decrease from 40.5 to 18.7 cents/kg of protein as the production capacity increases from 45.5 to 455.5 tons/month. The plant cost for the 10 times increased capacity is only 2.5 times higher. A further important cost factor is the yield. It depends not only on the quality of the raw material processed, but to a large extent on the processing methods used".

Table 34 gives a comparison of the cost of most important protein ingredients in the U.S.A. in 1970 (85).

Table 34

COST OF SELECTED PROTEIN INGREDIENTS, U.S.A., 1970

Ingredients	Percent protein	Bulk price 1/	Cost per pound of protein
	(percent)	(US¢/lb)	(US¢/lb)
Skim milk	36	20.0-25.0	55.6-69.4
Dry whole milk	26	40.0-45.0	153.8-173.1
Sodium caseinate	95	80.0-100.0	84.2-105.3 2/
Cottonseed flour 3/	55	10.0-12.0	18.2-21.8
Soy meal 4/	44	3.0-4.5	6.8-10.2
Soy grits 5/	53	6.5-6.8	12.3-12.8
Soy flour:			
Defatted	53	6.7-6.8	12.6-12.8
Enzyme active	53	6.9-7.0	13.0-13.2
Fatted or lecithinated 6/	53	8.6-8.7	16.2-16.4
Soy concentrate	70	19.0-24.0	27.1-34.3
Soy Isolate	95	35.0-40.0	36.8-42.1
Textured vegetable protein 7/			
Unflavored	50	30.0-33.0	60.0-66.0
Flavored	50	35.0-38.0	70.0-76.0

1/ Bulk price generally applies to orders in excess of 20 000 pounds. For smaller orders add US¢ 0.3 to 0.5 per pound.

2/ Some imported product is available at US¢ 36.8 to 42.1 per pound of protein.

3/ Denatured.

4/ Pet food grade.

5/ Grits are soy products in the 50 percent protein range with particles larger than 100-mesh in size. Flours are 50 percent soy products with particles smaller than 100-mesh in size. Grits are usually pet food ingredients.

6/ Defatted soy flour to which soybean oil or lecithin has been added.

7/ Extruded soy flour.

Source: Selected ingredient suppliers and users.
Hammonds, T.M. and Call, D.L., 1972, 2, Chem. Technol. (3), 156-162.

At present (May 1974) world market prices of soymeal are about 50 percent higher than 1970 (see Table 33).

Skim milk powder (world market) prices are at present about US$ 1 000/t, i.e. approximately twice as much as in 1970 (see also Table 20). Prices are even higher on domestic markets of major developed milk producing countries.

As regards the fat component of milk products and their imitations, it should be mentioned that the (world market) price of anhydrous milk fat is at present around US$ 1 600/ton (see also page 26).

International market prices for selected oils are given in Table 35. The upward trend prevailing during 1969–71 came to a standstill in mid-1972. From the end of 1973 prices increased again sharply to reach unprecedented high levels in early 1974. It is expected that prices will decline again in late 1974.

Table 35

INTERNATIONAL MARKET PRICES FOR SOYBEAN, COTTON, GROUNDNUT, COCONUT, SUNFLOWER AND FISH OIL

(US$/metric ton)

	Soybean	Cotton	Groundnut	Coconut	Sunflower	Fish
1965	270	258	325	360	294	216
1966	262	315	297	312	263	192
1967	216	360	283	319	212	127
1968	178	285	270	386	172	99
1969	198	241	332	347	213	149
1970	290	297	378	379	331	249
1971	304	338	446	354	375	221
Jan/Dec. 1972	270	324	393	215	326	182
Oct. 1972– Sept. 1973	367 1/	404 2/	485 3/	366 4/	401 5/	291 6/
Oct. 1973– March 1974	676	321	841	1 004	716	466
April 1973	375	411	456	360	363	258
March 1974	727	783	1 065	1 266	850	557

1/ Crude, U.S. cif Rotterdam (10 months only for 1972/73).

2/ U.S. PBSY, cif Rotterdam.

3/ Any origin, cif Rotterdam.

4/ Dutch, 5 percent, fob, ex-mill (Phil./Indonesian cif Rotterdam from Feb. 1974 on).

5/ Any origin, ex-tank Rotterdam.

6/ Peruv., semi, cif N.W. Europe (from March 1973; varying origin, crude).

FAO, 1973, Committee on Commodity Problems, Intergov. Group on Oilseeds, Oils and Fats, Working Paper CCP:OF/ST 73/CRS 2 Feb. 1973: figures for 1965–1972.

Oil World Weekly 17/XVII, April 26, 1974: figures for 1972–73, 1973–74 and 1974.

Suitability of oilseed proteins for use in imitation milks and imitation milk products

Economic aspects and technological suitability

Cost has been perhaps the most important factor in market penetration by imitation milks and imitation milk products. Major differences in ingredient costs of these products are due to the substitution of milkfat by vegetable fats (see Chapter 4).

Proteins of vegetable origin are also competing with milk proteins. Soy protein products especially have already successfully replaced milk protein in several imitation milk products. The use of groundnut and cottonseed, and other vegetable protein products will depend mainly on their competitiveness with comparable soy and milk protein products in particular with skim milk powder, both as regards functional criteria and cost 1/. While apparently a completely satisfactory substitute for skim milk powder has not yet been found, consumers have, to a certain extent, accepted products in which the milk protein was (at least in part) replaced by oilseed protein, in particular in infant formulae.

Nutritional aspects - Essential amino acid composition of selected protein (54)

Proteins are essential for human nutrition for the synthesis and maintenance of body tissue. Dietary proteins provide the essential amino acids most needed for tissue synthesis. For the adult human, it is now accepted that 8 amino acids are essential: isoleucine, leucine, lysine methionine, phenylalanine, threonine, tryptophan and valine. The infant requires histidine, in addition. The ability and efficiency of any protein to meet the requirements mainly depends on its essential amino acid composition.

The quality of a protein may be determined by comparing its amino acid composition with that of an amino acid pattern suggested by the FAO/WHO *ad hoc* Expert Committee on Energy and Protein Requirements. The provisional amino acid scoring pattern in milligrams of amino acid per gramme of nitrogen is given in the first column of Table 36.

Plant proteins in general are not efficiently digested and possess a lower nutritive value than animal proteins, as determined by the protein efficiency ratio (PER) 2/ or net protein utilization (NPU) 3/. This is mainly due to the deficiency of certain

---

1/ Oilseed protein, other than soy protein, might be used to a greater extent in countries producing these oilseeds, especially if the prices for the oilseeds concerned are lower than the world market prices and/or the governments of these countries would support the manufacture of edible protein from seeds. High prices for milk products in these countries would be a further incentive for the use of oilseed proteins in imitation milks.

2/ PER is the ratio of weight gain of a growing animal to the protein consumed. It is a measure of protein quality when determined under specific conditions; the caloric intake and the vitamin and mineral intake must be adequate and the protein must be fed at an adequate level for a specific period of time. When fed at surfeit levels, weight will no longer increase with protein intake and the ratio will fall. The PER has been used chiefly in feeding experiments on small animals. It is the simplest method of determining quality, requiring no chemical measurements, but it suffers from the possible error that weight gain may not be proportional to gain in body protein.

3/ NPU expresses in a single index both the digestibility of the protein and its biological value (NPU = digestibility x biological value). It represents the proportion of food nitrogen retained (NPU = N retained/N intake).

Digestibility: The proportion of food nitrogen that is absorbed (39).
Biological value: The proportion of absorbed nitrogen that is retained in the body for growth and/or maintenance (39).

Table 36

ESSENTIAL AMINO ACID COMPOSITION

Milligrammes of amino acid per gramme of total nitrogen

Amino acid	FAO 1971 1/	Cow's milk untreated 2/	Human milk 2/	Hen's eggs, whole 2/	Soybean 2/	Cotton-seed 2/	Ground-nut 2/	Sunflower seed 2/	Rapeseed 3/	Sesame seed 2/	BP Yeast concentrate 4/
Isoleucine	250	295	254	393	284	206	211	267	242	226	333
Leucine	440	596	548	551	486	370	400	401	428	419	486
Lysine	340	487	428	436	399	276	221	225	326	171	486
Total 'aromatic' amino acids	380	633	421	618	505	506	555	396	425	472	550
Phenylalanine		336	216	358	309	326	311	278	241	277	300
Tyrosine		297	205	260	196	180	244	118	184	195	250
Total sulphur-containing amino acids	220	208	185	362	162	178	150	212	296	289	156
Cystine		51	84	152	83	97	78	93	183	113	56
Methionine		157	101	210	79	81	72	119	113	176	100
Threonine	250	278	280	320	241	206	163	230	267	223	338
Tryptophan	60	88	105	93	80	78	65	85	74	84	81
Valine	310	362	284	428	300	290	261	317	310	288	235

1/ FAO Nutrition Meetings Report Series No. 52, 1973, Energy and Protein Requirements. Table 21, Provisional Amino Acid Scoring Pattern, suggested level.

2/ FAO Nutritional Studies No. 24, 1970, Amino Acid Content of Foods and Biological Data on Proteins.

3/ Eklund, A., Agren, G., Langler, F., Strenram, U. and Nordgren, 1971, Rapeseed Protein Fractions II - Chemical Composition and Biological Quality of a Lipid-Protein Concentrate from Rapeseed (Brassica Napus L.), J. Sci. Food & Agri., 22 (12):653-657 (from Mattil, K.F., 1972 (134)).

4/ Lainé, B., 1968, Du Pétrole aux Protéines, Indust. chim. agr., 1968, pp.1173-1178.

essential amino acids in plant proteins. It is, however, to be noted that proteins from different plant sources mutually supplement each other and blends of two or more proteins may possess a higher nutritive value than the individual proteins.

In Tables 36 and 37 data are presented (i) on the essential amino acid composition and (ii) nutritive value of certain vegetable proteins compared with milk and egg proteins (129). It can be seen that groundnut and cottonseed proteins are deficient in certain essential amino acids such as methionine, lysine and threonine. Soy protein is deficient in methionine and threonine. These proteins possess a lower protein efficiency ratio and net protein utilization than milk or egg proteins.

Table 37

NET PROTEIN UTILIZATION 1/ (NPU) AND PROTEIN EFFICIENCY RATIO 1/ (PER) OF DIFFERENT PROTEINS

Food	NPU	PER
Hen's egg	93.5	3.9
Cow's milk	81.6	3.1
Cow's milk casein	72.1	2.9
Whey protein	83.9	-
Fish	79.5	3.6
Fishmeal	65.8	3.4
Soybean	61.4	2.3
Soyflour	56.0	-
Groundnut	42.7	1.7
Groundnut protein isolate	-	1.9
Cottonseed meal	52.7	2.3
Sunflower seed	58.1	2.1
Sesame seed	53.4	1.8

1/ See footnotes 2 and 3 on page 69.

FAO Nutritional Studies No. 24, 1970. Amino Acid Content of Foods and Biological Data on Proteins.

5.3 Leaf Protein

Background

D. Halliday (1970) reports that work on the extraction of protein from leaf materials in a form suitable for incorporation into the diets of human beings was first carried out by R.E. Slade and his collaborators at the ICI Research Station, Jealott's Hill (United Kingdom) in the late 1930's and early 1940's (84). Considerable research on the extraction of protein from leaves has been carried out since then in the United Kingdom (e.g. by N.W. Pirie at the Grassland Research Institute and at Rothamsted); in India (by N. Singh at the CFTRI, Mysore); in Jamaica (by C.B. Mendes); in Pakistan (by F.H. Shah et al.); in Nigeria (by I.A. Akinrele and by O.L. Oke); in Hungary (by J. Hollo and L. Koch in cooperation with Anhydro, Denmark, and Alfa-Laval, Sweden); and in the U.S.A. (by E.M. Bickoff and G.O. Kohler).

Before outlining the main basic steps for the production of leaf protein, it should be noted that there are mainly two approaches in tackling the manufacture of leaf protein: one which is followed, e.g. by Kohler and Bickoff at the Western Regional Research Laboratory, Agricultural Research Service, USDA, California (16, 113, 114), and the Hungarians, J. Hollo and Koch (95, 169), is aimed primarily at obtaining two types of fodder for ruminant and non-ruminant animals, the Americans using this approach as a first phase in a two-phase programme; the second is aimed at obtaining pigment-free palatable LPC in addition to the other two products. The second approach, followed e.g. by N.W. Pirie (185) in U.K. is concentrating on achieving the maximum practical extraction to obtain edible LPC.

The basic steps for the preparation of LPC consist of:

(i) rupturing the cells by grinding the fresh leaf material;

(ii) separating the juice from the fibre by pressing;

(iii) concentrating and/or drying the juice without further separation; or

(iv) separation into a green protein coagulate (LPC) plus a clear liquor (leaf solubles); the coagulate LPC can be stabilized by, for example, adding salt, or drying, and the solubles fraction by concentration and/or drying.

The most suitable raw materials for LPC production appear to be specially grown crops such as alfalfa used at the optimum stage of maturity and cereals such as wheat. Waste materials such as pea vines or sugar beet tops (169) and weeds like the water hyacinth (177) may also be suitable.

Crude dry LPC is reported to develop rapidly unpleasant off-flavours at room-temperature due to oxidation of the lipids. Extraction of lipids improves storage properties.

The nutritive value depends largely on the drying temperature used. Provided great care is taken during drying, it appears LPC can be obtained with a nutritive value similar to that of soya protein. For use in imitation milks, a bland powder (as obtained by solvent extraction of the lipids) would be necessary.

The prospects for the use of LPC as a means of helping the protein problem in developing countries have been summarized by the Protein Advisory Group at its 17th meeting in New York, N.Y., U.S.A., 25-28 May 1970, when the group considered a request for advice received from the British Ministry of Overseas Development on the prospects for leaf protein concentrate (LPC) as a means of helping the protein problem in developing countries and on the need for further investigational work to which aid funds might be applied. The PAG adopted the following statement (58):

"With regard to the present interest in the development and use of various 'unconventional' protein concentrates, though recognizing the limitations on them, the PAG did not feel it appropriate to give a simple recommendation for or against further work on leaf protein. It noted the good biological value and useful vitamin A content of leaf protein; the many sources from which it can be prepared; the several forms that the product can take; the possibility of integrating production with the preparation of other products as a means of reducing costs; and acknowledged the considerable volume of work on the subject by Mr. N.W. Pirie and many others over the last two or three decades.

The Group, however, drew attention to certain disadvantages of leaf protein compared, for instance, with oilseed protein concentrates. These are, in particular, its colour, flavour and lack of stability in the less processed forms and its lack of economic competitiveness in the bland, stable powder form. The balance of expert opinion from various research groups, provided to PAG both in correspondence and at its meeting and also that appearing in recent publications, was that the idea of small-scale village production of the crude leaf protein product was impractical. PAG endorsed this view. Leaf protein has then to be judged in terms of the bland, stable powder form, which would be produced on a large scale and which would, therefore, be exposed to direct economic competition with oilseed protein concentrates and perhaps eventually with fish protein concentrate and single cell protein as well. As with certain of these other products, the Group saw the possibility that leaf protein might be considered initially as an animal feed supplement.

The Group heard estimates that a crude product, produced from alfalfa and containing 70 percent protein, is likely to cost at present 10-20 US¢/lb, not including profit or marketing costs. For a solvent-extracted product, the price would be two to three times higher, even with the economic benefits of large-scale production (25 million pounds per year of product).

The PAG recognized that further research on a laboratory and pilot scale into the feasibility of leaf protein sources and methods for their extraction would be desirable in appropriate institutions. In view of the large amount of data already available and the limited practicality presently indicated, it could not accord such work a high priority or recommend the use of funds intended for the assistance of developing countries.

Furthermore the Group felt that any major expenditure on large-scale processing operations in a developing country, even if these were of an experimental nature, should only be embarked upon after a thorough feasibility study. This would take into account all the relevant factors such as type of product, process control, manner of distribution and costs of production (estimated reasonably from earlier work) and comparison with alternative routes to the aid objective."

Commercial production

In the meantime the two processes mentioned initially have reached the commercial stage: the Vepex-process developed in Hungary and Sweden (169) and the PRO-XAN process developed in the U.S.A. (114). The latter process (the name is derived from protein xanthophyll concentrate) produces as Phase I (a) standard grade alfalfa meal, and (b) a 50 percent protein high xanthophyll concentrate for poultry, and (c) a concentrate for use as an unidentified growth factor supplement for livestock. Phase II of the programme aims at the development of further steps to yield pigment-free palatable LPC plus xanthophyll concentrate from the intermediate or end products. E.M. Bickoff and G.O. Kohler have reported to the PAG that the commercialization of Phase I has been carried out through the cooperative efforts of the Western Regional Research Laboratory and a large commercial firm

in southern California which harvests and processes about 300 000 tons of alfalfa per year and produces about 60 000 tons of dehydrated meal for poultry and cattle. By incorporation of the Phase I process in their normal operations several thousand tons of 50 percent protein-high xanthophyll LPC are produced without lowering significantly the protein content of the alfalfa meal as the PRO-XAN process removes only a small amount of the protein. The operation is reported to be commercially successful. Pilot plant development of Phase II is underway with two large alfalfa processors, one in the U.S.A., one in Europe. As regards prices, PAG Statement No. 11 quoted above is commented upon as follows (Extract from PAG Bulletin 1973, Vol. III, No. 1, pp.19/20: "Commercial Production of Leaf Protein for Animal and Human Use" by E.M. Bickoff and G.O. Kohler, Western Regional Research Laboratory, Agricultural Research Service, USDA, Berkeley, California, U.S.A. (16)):

> "The forage dehydration industry sells its normal products, largely 17-20 percent protein alfalfa, at a retail price of US\$50-60 per ton FOB plant or 12-15 cents/lb of protein assuming no other value recovered. These prices include profits to the farmers and processors. The raw material, fresh forage in the field, sells for US\$10-20/dry ton or 2.5-5 cents/lb of protein. Thus fresh alfalfa provides a very low cost raw material for protein recovery. When the returns from all the products are considered, it is felt that previously quoted figures of 10 to 20 cents per pound for the crude protein product will be found to be unduly high. These earlier figures do not give proper weight to the returns from the various animal feed products, the dehydrated meal, the high-protein poultry feed supplement and the molasses-like solubles concentrate."

The Vepex process is used in a plant in Tamasi (near Lake Balaton) in Hungary (169, 184). It has been reported that the plant processes 8 tons per hour of green material (mainly alfalfa), the yield being 5 percent. Two further facilities which are in the planning stage will process 20-25 tons per day with a yield of 6 percent. The Vepex process is described

> "as being roughly similar to that used in sugar processing. The greens are mechanically milled, and the resulting slurry is pressed to obtain juice. When the juice is heated to 75-85°C, protein coagulates and is recovered in a two-stage centrifugal operation.
>
> The supernatant material left after coagulation and centrifugation is rich in nutrients; it is used to produce fodder yeast. The thin liquor remaining after the yeast harvesting is mixed and pressed with fibres obtained during the initial milling. This mixture is then dried and pelleted to produce roughage. Yeast and LPC can be mixed to meet market demand.
>
> Although a small amount of cooling water is needed (for external cooling purposes), the Vepex process is a completely closed loop, which means that no wastes are discharged.
>
> The Hungarian state licensing agency has announced that it will make the Vepex method available on a world-wide basis."

5.4 Single Cell Protein (SCP)

Background

The use of protein (and vitamins) from yeasts grown on carbohydrate-containing media both for feeding animals and man (the commercial production of Torula yeast in Germany during World War I and the yeast extract Vitam-R may be mentioned as examples) and for the preparation of nutrient media for microorganisms is well-known. It is also well known by microbiologists that certain microorganisms can grown on petroleum, that they are found in the bottom of oil tanks and even under the tarry surfaces of roads. Felix Just reported in 1952 that he had succeeded in growing yeast on pure hydrocarbons of the paraffinic family by isolating strains and defining growth conditions. Alfred Champagnat (24) and his research group of the Sociétè Française des Pétroles BP at Lavera started their investigations on growing microorganisms on gas oil fractions and to explore techniques for large-scale cultivation of yeasts on such hydrocarbon fermentation media. The main difference between growing yeasts on petroleum instead of sugar is:

(i) the need to keep the waxy hydrocarbons in the watery medium in suspension by stirring the medium strongly;

(ii) the greater demand for oxygen, hydrocarbon molecules having no oxygen, whereas sugar molecules contain about 50 percent oxygen, and

(iii) the control of the temperature, i.e. the need for an efficient cooling system to cope with the cells' increased output of heat.

The material balance comparison between carbohydrate and hydrocarbon fermentation given in Table 38 also shows that carbohydrate fermentation needs considerably higher quantities of substrate than fermentations from hydrocarbons (76).

Table 38

MATERIAL BALANCE COMPARISON BETWEEN CARBOHYDRATE AND HYDROCARBON FERMENTATION

(in pounds)

Process	Substrate	Oxygen Needed	Cells
Carbohydrate	200	67	100
Hydrocarbon	100	200	100

Gatelier, C.R., 1970, Proceedings SOS/70, Third International Congress Food Science and Technology, Washington, D.C., August 1970, 561-564.

The pH of the substrate has to be controlled as in the case of sugar-containing media.

Carbohydrate substrates

A. Spicer (173) reports the completion of the research stage of a fungal protein, the aim being a protein suitable for human consumption with a profile in which neither lysine nor the sulphur amino acids would be limiting and with textural and structural qualities making texturization superfluous. The carbohydrate substrate could be sweet potato, cassava, starches or lactose. Another important aspect of processing SCP is its potential for

converting waste containing cellulosic material and/or waste starch or sugars (13, 86, 101, 103, 144, 173) into microbial protein for animal feed. As an example, it might be mentioned that a product based on waste from a pulp mill in Finland has successfully replaced skim milk powder in feeding trials with growing pigs (73).

Hydrocarbon substrates

The two major processes for manufacturing SCP from hydrocarbons are (98, 191):

(i) the gas oil, and

(ii) the normal paraffin process.

The fermentation, using gas oil from which the yeast itself selects the fermentable normal paraffin of the gas oil, must be attached to a refinery since only the normal paraffins of the gas oil are fermented and the rest is recovered and repassed to the refinery for further processing. The production process consists of three phases:

(i) production of yeasts by the above fermentation process;

(ii) separation of the biomass from the remaining gas oil, (i.e. the part which cannot be metabolized), and

(iii) the elimination of the last traces of gas oil from the yeasts.

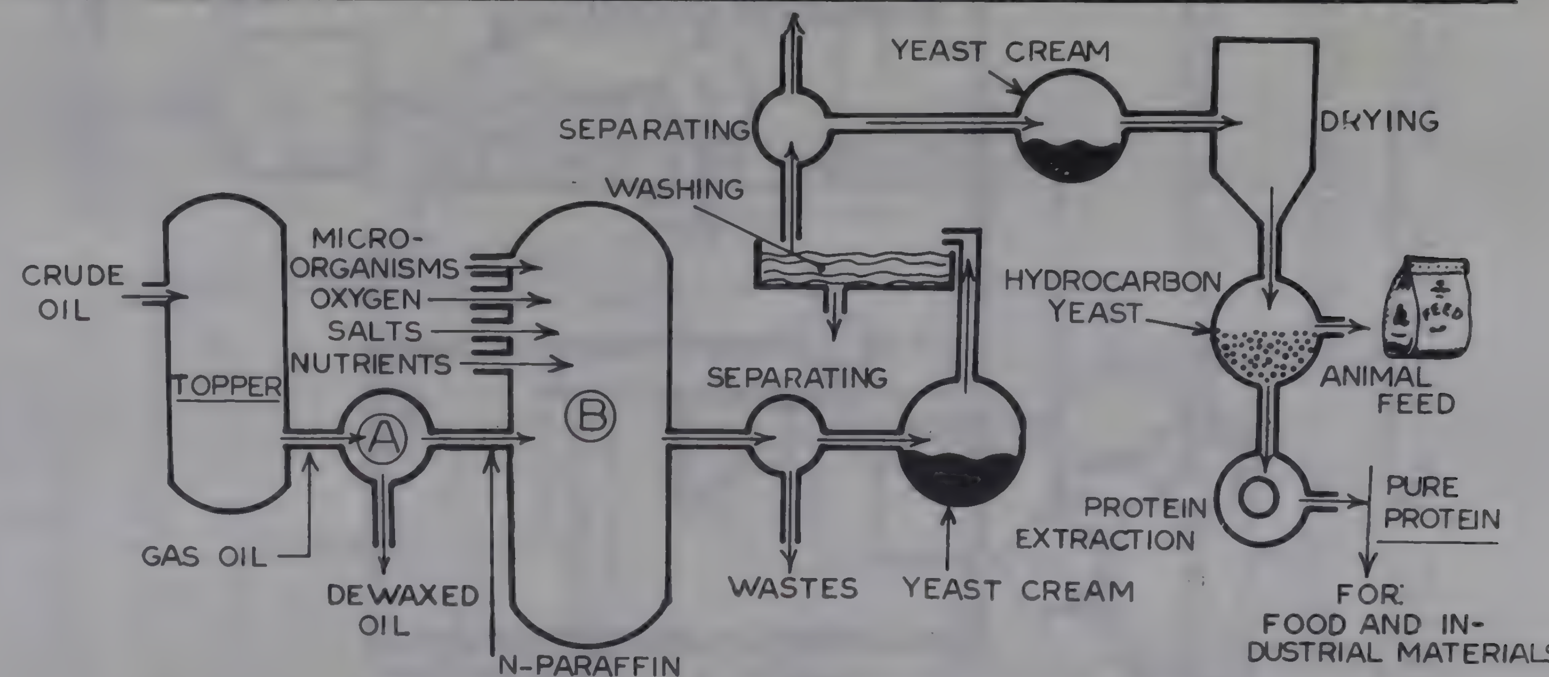
The last mentioned phase of purification is being carried out with the use of selected solvents.

The normal paraffin process uses, as feedstock, pure normal paraffins from gas oil preselected by molecular sieve arrangement in the refinery. This process is less complex than the first mentioned one and, therefore, cheaper, resembling the production of yeasts from molasses. Solvent treatment is not necessary as impurities can be removed by water washing of the yeast cream separated from the medium. After separation, the yeast slurry is spray dried. Flow sheets of the process are given in Figures 10 and 11 (191). Other oil companies, like the American Standard Oil Co. and Shell, are also studying protein production. Shell is conducting SCP research based on the use of multiple gaseous substrates as feedstock for bacterial growth, in particular the fermentation of an equilibrium mixture of methane/ethane by a mixture of two bacterial strains. The end product is claimed to be a bacterial biomass of constant composition and of relatively high cystine/methionine content. Where flared gas is readily available, methane could become one of the main future substrates for SCP production in the 1980's.

Imperial Chemical Industries Ltd. developed a process based on methanol and the use of bacteria. A flow sheet of the process is given in Figure 12 (102, 152). Their main reasons for choosing methanol as a substrate are the availability of methanol from a number of sources which are additional to petroleum, such as natural gas and coal, that the price for methanol is unlikely to rise as rapidly as that of normal paraffins, that methanol is soluble in water and so reduces fermenter design problems and that it is volatile and easily removed from the SCP during drying. One further reason given by ICI is that methanol is a very pure material as sold industrially. Its content of polycyclic aromatics is very low and near to the limit of detection.

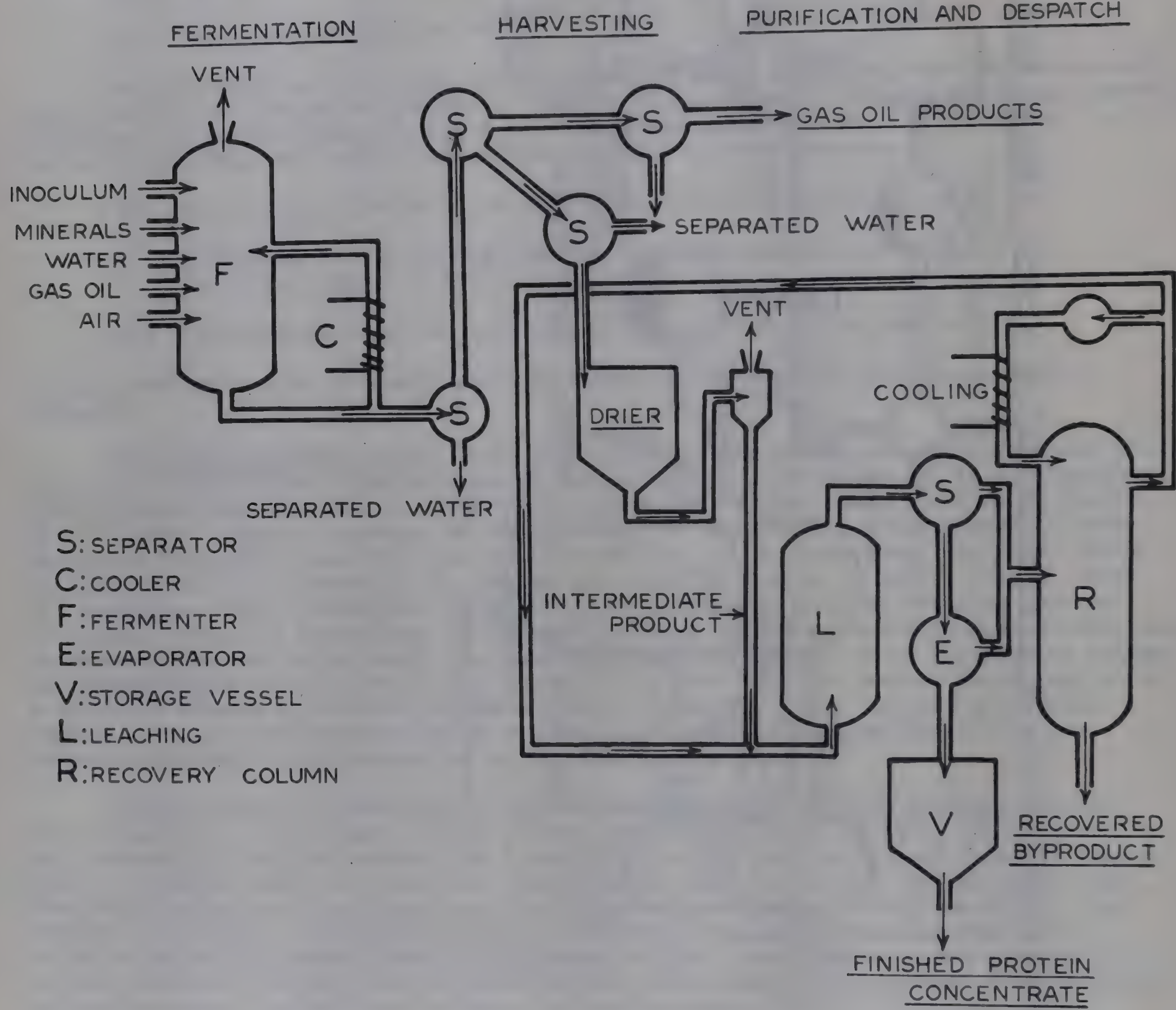
It would appear that these "second generation" processes, i.e. the ones using methane and methanol are already well advanced and might produce SCP cheaper than the "first generation" plants, the feedstocks of which are normal paraffins and which are the only ones actually in production. These substrates must pass stringent food acceptability tests.

FIG. 10: PRODUCTION OF HYDROCARBON YEAST FROM N-PARAFFIN



(A) N-PARAFFIN SEPARATING. (B) CONTINUOUS FERMENTATION.

FIG.11 : HYDROCARBON YEAST BY GAS OIL PROCESS



S: SEPARATOR
C: COOLER
F: FERMENTER
E: EVAPORATOR
V: STORAGE VESSEL
L: LEACHING
R: RECOVERY COLUMN

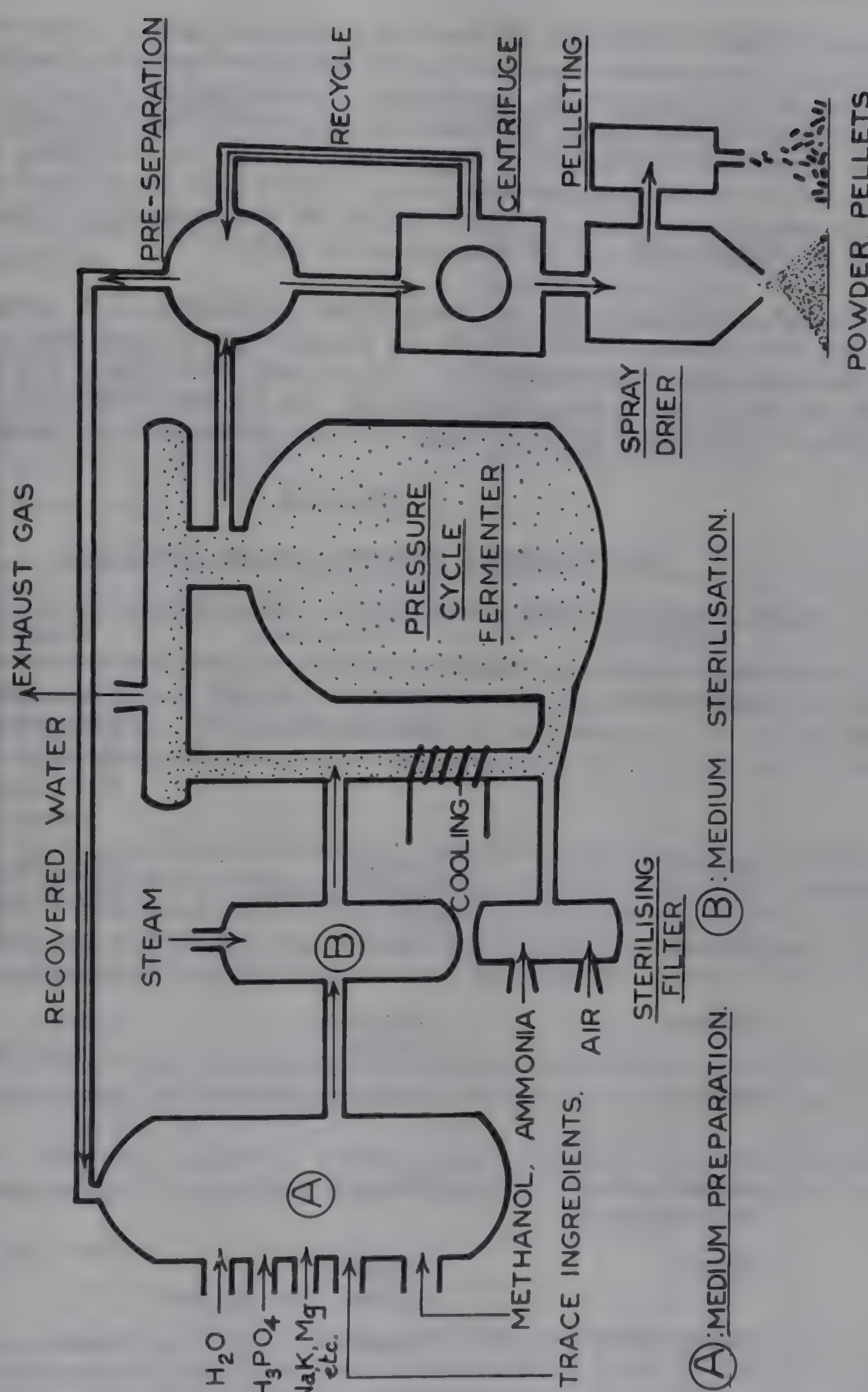


FIG.12: ICI PROTEIN PROCESS

Existing plants and future plans

The capacities of the BP plants at Lavera (producing Toprina "L" from the gas oil fraction of petroleum) and Grangemouth (producing Toprina "G" from purified normal paraffins) are 20 000 and 4 000 t per annum respectively yeast powder, with approximately 60 percent protein (77).

In Europe, plans for major production units are being implemented. Liquichimica Biosintesi S.p.A. have under construction a 100 000 t unit in Reggio Calabria, Italy, for the production of SCP from normal paraffins. Italproteine S.p.A., jointly owned by BP and ANIC, a subsidiary of ENI (Ente Nazionale Idrocarburi) have awarded contracts for construction of a unit of similar size in Sardinia. ICI is designing a 100 000 t per year plant on the basis of results obtained in a 1 000 t per year pilot plant which has been operating for nearly two years. Construction of the commercial plant is reported to start in 1974, and the plant will be in operation in 1977.

The U.S.S.R. programme has not been given publicity, but it was reported at the meeting of the PAG Working Group on SCP in Moscow (1971) that SCP was being produced on an industrial scale in the Ural mountains. It is said that there are three plants, at least one of which is of 50 000 t capacity with gas oil as the feedstock. It is known that the U.S.S.R. plans to produce 1 million tons of feed-grade SCP per year (98).

Table 39

SCP PROCESSES CURRENTLY BEING DEVELOPED

Substrate	Organism	Companies involved
N-Paraffin	Yeast (or bacteria)	Liquichimica Kanegafuchi British Petroleum Gulf Research & Development
Gas oil	Yeast (or bacteria)	British Petroleum Government of U.S.S.R.
Methanol	Bacteria	Imperial Chemical Industries
Ethanol	Bacteria Yeast	Exxon Amoco Food Company
Methane	Bacteria	Research Ltd. Shell
Starch and Carbohydrate	Fungi	Rank Hovis McDougall
Sugars	Fungi (Yeast and bacteria)	Tate and Lyle
Carbon Dioxide	Algae	Institut Français du Pétrole
Cellulose	Yeast or Bacteria	General Electric Co.
	Fungi	Finnish Pulp and Paper Association

Wells, J., 1973, Notiziario CTIP, XIV, Dec., Rome, Piazzale Douhet, Italy

Table 40

DESIRABLE PROPERTIES OF MICROORGANISMS USED
FOR PRODUCTION OF SCP

Technical	Composition of organism
Rapid growth on simple media in suspended culture	Protein, fat, carbohydrate content of high quality
Simple separation	Non toxic
Freedom from contamination - Stable fermentation	Essential amino acids
Efficient energy utilization	Highly digestible
Tolerance towards toxic compounds in the medium	Good taste
Tolerance towards mechanical strains during culture process	High nutrient content
Easy protein extraction	Capable of genetic modification

Wells, J., 1973, Notiziario CTIP, XIV, Dec., Rome, Piazzale Douhet, Italy

It has been reported recently that pressure of public opinion has caused two Japanese companies, Dainippon Ink and Chemicals, Inc. and Kanegafuchi Chemical Industry Co., to postpone their production plans. Both had planned to be producing at an annual rate of 60 000 t in 1973 and two other Japanese companies had planned production on a similar scale in 1974.

Information from other countries is scant. China is reported to be launching an ambitious programme of SCP production. Other countries, such as India and Czechoslovakia are at the pilot-plant stage. Several petroleum companies and universities in the U.S.A. are studying various aspects of SCP production on an experimental scale. Among oil-producing countries showing interest in SCP production are Kuwait, Brazil, Libya and Indonesia.

The different substrates used by leading processors presently developing processes are given in Table 39, the desirable properties of microorganisms used, in Table 40 (191).

With regard to the economic aspects, technological suitability, nutritional and health aspects, the following picture emerges on the basis of the rather scarce information available.

Economic aspects

Data and estimates concerning the economics of SCP production were given at an expert group meeting on the manufacture of proteins from hydrocarbons, held by UNIDO in October 1973 in Vienna by F. Giacobbe, Director of Process Department, CTIP (79), B.M. Lainé, Technical Manager, BP Proteins Ltd. (122, 123), F. Fussman and G.D. Kerns, the Lummus Company, Bloomfield, New Jersey, U.S.A., and P.G. Cooper and R.S. Silver, Gulf Research and Development Company, Pittsburgh, Penn., U.S.A. (74), N. Tanahashi, Manager, Development Division, Research and Development Department, Kanegafuchi Chemical Industry Co. Ltd., Osaka, Japan (176), and R.J. Young, Overseas Protein Manager, Agricultural Division, ICI Ltd., Billingham, U.K. (200).

Since that meeting, world energy prices have greatly increased. Therefore some of the estimates provided at the meeting would appear to be too low.

The range of substrate costs given in Table 41 is based on the figures given in the draft report of the UNIDO meeting (178) and on present-day standards (March 1974) supplied by A.E. Rout, ICI, Agricultural Division (personal communication).

Table 41

RANGE OF SUBSTRATE COSTS FOR PRODUCTION OF SCP

Substrate	Microorganisms used	Feedstock Cost $/t	Yield t of SCP/t of substrate	Substrate cost $/t of SCP (dried product)
Normal Paraffins	yeast	60-150-200	1	60-150-200
Methanol	bacteria	40-75-100	0.5	80-150-200
Methane	bacteria	5-60	0.6	8.5-100
Ethanol	bacteria	60-125-150	0.6	100-200-250
Molasses 1/	yeast	20-40	0.25	80-160

1/ 50 percent assimilable carbohydrates.

Taking into account that the methanol-based product contains 80 percent crude protein compared with 65 percent crude protein in the n-paraffin-based products, the substrate cost per unit of protein of the methanol-based products would be lower than that for n-paraffin-based products.

As regards the size of SCP plants, Lainé considered that for n-paraffins production, there is no specific limit, provided enough n-paraffins are available. In order to benefit from the low costs of large-scale production, a central unit of 100 000-500 000 t/year could be grafted to a very large refinery and used to feed a number of smaller protein plants located according to the market requirements for SCP.

With the gas oil process, the plant must be connected with a refinery which will supply the feedstock and receive the returned non-paraffinic fraction. Consequently, the size of the plant depends on the availability of the middle distillate from the chosen refinery; it also depends on the quantity of paraffins present in the available feedstock, on the commercial value put for the raw and dewaxed middle distillate if maximum use of the premium for dewaxing is looked for.

A rough summary in terms of protein yield is given in Table 42.

Table 42

YIELD OF SCP IN T/YEAR DEPENDING ON TYPE OF NORMAL PARAFFINS AND SIZE OF THE REFINERY

Middle distillate boiling range	Refinery size 2 million t/year	10 million t/year
330–380°C		50 000
300–380°C	20 000	100 000
250–380°C (maximum potential)	50 000	200 000

Lainé, B.M., 1973, Working Paper, UNIDO ID/WG. 164/27

Lainé therefore concludes that not only can SCP be produced alongside refineries of a standard size in Western Europe, but also near smaller refineries, such as are now built in many parts of the world. Because methanol can be produced from a range of feedstocks and is already available on the world market for other purposes, adequate supplies might be available for SCP production.

F. Giacobbe (79) has estimated the mature year profit of an SCP plant based on n-paraffins with a capacity of 100 000 t/year. Giacobbe arrives at approximately US$230/t direct manufacturing costs, based on the following assumptions:

- Process yield equal to 870 kg of n-paraffins for 1 ton of SCP including process and mechanical losses.

- Cost of n-paraffins equal to 15¢/kg.

- Cost of chemicals and utilities based on price in West Europe.

- Average cost of operating personnel equal to US$760/man-months.

- Packaging cost equal to 0.2¢/kg based on the assumption that the majority of the product will be shipped in bulk.

According to Giacobbe's calculations, the cost of n-paraffin raw material is the most important cost item followed by the utilities and chemical costs which both account for 35.5 percent of the direct manufacturing cost. The selling price was assumed to be US$424/t resulting in a return on investment of 15.8 percent.

On the basis of his economic analysis of the process, F. Giacobbe arrives at the following conclusions:

"The economics of manufacturing SCP is highly dependent on the price of n-paraffins. A 20 percent increase in the price of n-paraffins would decrease the return on investment from 15.8 to 11.6, while a decrease in price of the same amount will increase the return on investment to 20 percent. Hence any manufacturing operation will require a low cost n-paraffin without great variation. The composition should be within a critical boiling range and the use of n-paraffins with less than 15 carbon atoms is not recommended. A research effort should be devoted to improve the selectivity of the yeasts used.

- The SCP plant should be built in a location where large quantities of good quality water are available and where the cost of fuel is low.

- The economics of producing SCP are most sensitive to changes in the selling price. Conservative selling price assumptions are recommended when evaluating the feasibility of operation when profitability may seem tight under certain circumstances.

- SCP plants are capital intensive and sensitive to sales volume. A decrease in sales will sensibly reduce the return on investment. However, market penetration should be conservatively evaluated. Preplanning design for future expansions should be kept to a minimum while the plant design must be suitable for trouble-free operation.

- The optimum plant capacity is indicated to be 100 000 t/year on the basis of the technology available. Larger plant capacity will become attractive in the future when the design of fermenters, larger than those presently available, will be developed."

The above expert group meeting arrived at very similar conclusions as regards the optimum plant size. It stressed that for optimum economic performance, the local situation would have to be analyzed carefully with regard to sales prospects, ultimate distribution network, availability and cost of raw materials and financing costs and terms.

The price of normal paraffins has risen due to the price increase of petroleum. There is, however, also scope for cost reductions. Mutation work may also achieve proteins of better biological value by altering the amino acid profile. Operating costs may be lowered by the development of strains with higher working temperatures, thus decreasing requirements for cooling which is an important part of overall operation costs.

In general it can be expected that as processes improve and production expands and diversifies, SCP costs will become increasingly competitive.

Technological suitability

The SCP (yeast powder) presently available occurs in the form of a creamy powder. Taking into account the resources of the petroleum industry and their determination to enter the field of new food sources, it is difficult not to believe in a utilization for food purposes in some years to come.

Nutritional and health aspects

Tables 36 and 43 which give the amino acid composition of some SCP materials show that the methionine and cystine contents are low; however, by adding 0.3 percent of methionine, the biological value of the commodity would be brought up to that of skim milk powder. As far as protection of consumer health is concerned, special care has to be given to the removal of any trace of toxic substances such as aromatic compounds with a carcenogenic nature. Further bacteria and yeasts have high nucleic acid content because of their fast growth. It has been reported that the ingestion of nucleic acid at high levels (PAG recommendations for adults; not more than 2 g daily of nucleic acid) by men results in high plasma uric acid levels, which would make such material unsuitable for direct human use. However, progress has been made in developing procedures for decreasing considerably the percentage of nucleic acid in SCP after harvest but they may add to the cost of edible SCP.

Table 43

CRUDE PROTEIN (N x 6.25) CONTENT AND AMINO ACID COMPOSITION OF SOME SINGLE CELL PROTEIN MATERIALS

Material	Crude protein per cent (dry basis)	Essential amino acids mg per g total nitrogen									
		Isoleucine	Leucine	Lysine	Methionine	Cystine	Phenly alanine	Tyrosine	Threonine	Tryptophan	Valine
Whole hen's egg (Reference)	-	393	551	436	210	152	358	260	320	93	428
Esso-Nestlé bacterial protein 1/	-	225	350	405	87	38	180	-	250	56	280
Candida utilis - Yeast 2/	-	239	475	300	69	-	538	388	338	150	238
BP Yeast (n-paraffin substrate) 2/	69	281	438	438	113	69	275	219	306	88	338
BP Yeast (gas oil substrate) 2/	75	331	488	488	100	56	300	250	338	81	363
TPI *Rhizopus* sp. - Fungal mycelium*	33	206	278	323	93	88	194	172	224	76	240
UWO *Graphium* sp. - Fungal mycelium 3/	-	318	505	530	112	-	280	-	106	-	410
IFP *Spirulina platensis* - Alga 4/	75	390	556	285	165	59	283	302	326	100	420
IFP *Spirulina maxima* - Alga 4/	67	375	540	282	152	60	275	283	320	101	410
Chlorella - Alga	-	244	438	427	93	75	305	248	208	85	347

*Analysis carried out at the Tropical Products Institute.

1/ Enebo, L. (1970) Single-cell protein. Proceedings of the International Biological Programme Symposium, Stockholm, 1968. Published as "Evaluation of novel protein products". Pergamon Press, Oxford, 1970, p. 93.

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4/ Institut Français du Pétrole (1970) State of development of the IFP algae process at December 1970. Report to Protein Advisory Group, Ref. 18730.

Spensley, P.C., D. Halliday and E. Orr, 1973, Tropical Science, XIV, 3, 203-233.

Stringent toxicological testing was necessary before the use of SCP either as feed or food could be justified. BP appointed independent laboratories to undertake an extensive programme of animal testing.

The successful outcome of feeding trials from normal paraffin SCP has been followed by certain Governments' clearance for the use of hydrocarbon SCP in animal feeds. So far, it is reported, the use of either Toprina "G", Toprina "L" or both products is permitted for use in animal feeds in Belgium, Britain, Ireland, France, Denmark, West Germany, the Netherlands, Italy and South Africa (124).

The U.S.S.R., which is producing SCP has presumably also cleared it. SCP produced from normal paraffin by Kanegafuchi and Dainippon, is also reported to have been cleared for animal consumption in Japan. However the two companies suspended their plans for production as mentioned above.

For a summary of the results of the experimental testing, the opinion of the PAG may be quoted (56):

<u>For animal feeds</u>

"At the present time SCP products grown in purified petroleum hydrocarbon fractions are safely used in animal feeding at a practical level. They can be particularly useful in feeding poultry and swine. Hydrocarbon-grown SCP is not inferior in nutritive value to that grown on carbohydrate substrate such as molasses, sulfite liquors and agricultural waste. It can also be expected to make a considerable contribution to the amount of animal protein available for human consumption. No carcinogenic, mutagenic or embryotoxic effects have been observed from the use of such material in animal feeds and there is no adverse effect on the quality and safety of animal products produced in this way".

<u>For human consumption</u>

"Yeasts grown on molasses, sulfite liquors and vegetable waste have established their safety and nutritional value when employed as a minor component of human diets. All of the data from experimental and farm animals suggest that properly selected and produced SCP grown on purified petroleum hydrocarbons will be similarly useful but appropriate clinical trials (PAG Guideline No. 7), preceded by preclinical tests referred to above will be required before each product is approved for this purpose".

As the case of Japan shows, the influence of public opinion might retard acceptance of SCP grown on petroleum by-products considerably.

6. SUMMARY AND CONCLUSIONS

6.1 Summary

The publication consists essentially of two parts. The first part deals with (i) the definition of the term imitation milk and other terms in use for milk product substitutes, (ii) the nutritive value of cow's milk and the postulate that imitation milks and imitation milk products should not be nutritionally inferior to the milk or milk product they are to replace, (iii) the composition, ingredient cost, prices and market penetration of imitation milk products in important milk producing countries, and (iv) the market penetration and/or demand substitution by imitation milk in 1980.

The second part deals with technology, production, prices and nutritive value of protein raw material of animal and plant origin which are already used in the manufacture of imitation milks and imitation milk products, namely (i) milk protein in its various forms and fish protein concentrate and (ii) soybean protein and groundnut protein, and with protein sources which at present are only used for feeding animals, which however, might provide in the future protein for inclusion in imitation milk products: namely (iii) cottonseed and other oilseed proteins such as rapeseed, with (iv) leaf protein and (v) single cell proteins.

The terms imitation milk and imitation milk products have been defined in the FAO/WHO Code of Principles concerning Milk and Milk Products which has been accepted by 71 countries, whereas other terms such as "artificial milk", "synthetic milk", "vegetable milk", etc., lack internationally agreed definitions.

A survey carried out by the International Dairy Federation on imitation milk products comprising 22 IDF member countries indicated that imitation ice-cream, a "filled" milk product, has a high share of the total ice-cream markets in Sweden (90 percent), the U.K. (82 percent), Japan (50 percent), the Netherlands (50 percent) and Belgium (45 percent). In the U.S.A. the share of imitation ice-cream was 7 percent (15 percent of the frozen dessert market in the 13 states where the products can be sold). Coffee whiteners have penetrated Sweden's coffee cream market to the extent of 10 percent. In the U.S.A. they took about 35 percent of the light cream market. Imitation whipping cream is reported to have achieved some 50 percent market penetration in the U.S.A. The protein component of coffee whiteners and imitation creams is normally either sodium caseinate or soya protein.

Infant foods imitate mother's milk and should have a nutritional value similar to that of human milk. A number of such foods are "filled" milks. The American Academy of Pediatrics Committee on Nutrition has recommended that "if imitation milk products are to replace milk in the diet, they must contain adequate quantities of the essential nutrients to approximate the qualities inherent in milk".

An estimate of medium and high level market penetration and/or demand substitution by imitation milks in 1980 based on FAO demand projections for milk and milk products 1980 shows that imitation milk might close part of the project gap (of some 20 million tons of milk equivalent).

Existing and potential protein raw material

Animal protein ingredients in imitation milks are skim milk powder, which is essential for the manufacture of most filled milk products, and other products derived from milk: edible casein and caseinates, co-precipitates, whey powder and whey proteins.

Whey protein manufacture is dealt with in greater detail as the whey disposal problem is becoming increasingly acute as a result of expanding cheese production and the enforcement of antipollution laws. Increasing whey powder prices have strengthened the trend to whey processing rather than its treatment for sewage. Special whey protein products prepared by means of modern membrane processes (reverse osmosis, ultrafiltration, and electrodialysis) are of interest for high priced products such as infant formulae.

The only other animal protein used in imitation milks appears to be fish protein concentrate (FPC). Commercial production of imitation milk using FPC is getting underway in Chile with technical assistance from FAO.

Oilseed protein. Major soybean-producing countries are the U.S.A., China, Brazil, the U.S.S.R., Indonesia, Mexico, Canada, Korea (DPR), Korea (Rep.), and Japan. Soy protein food products such as tofu (bean curd) or tempeh (a fermented soy product) have played and are still playing an important role in the diet in East Asia.

An immense amount of research has been devoted during the last 50 years to the development of soybean protein products, in particular in the U.S.A., with the result that soya flours, concentrates and isolates are now available, with functional and nutritive properties which make them attractive to the food industry. Soy protein products are used in certain infant formulae (flours and isolates), in whipped toppings, in imitation powders (isolates), and they may replace casein in coffee whiteners because of high casein prices. A soy protein soft drink called "Vitasoy" is successfully marketed in Hong Kong. Corn-soy-milk (CSM), a food blend distributed by USAID to feed undernourished people throughout the world is an interesting example of combining protein sources for supplementary purposes to arrive at a product corresponding to the nutritive qualities required.

The ten major groundnut-producing countries are India, China, Nigeria, the U.S.A., Brazil, Senegal, Burma, Indonesia, South Africa, and the Sudan. Contamination of groundnuts with aflatoxin owing to infestation with Aspergillus flavus constitutes a potential danger to consumers of contaminated groundnuts or groundnut products. Control, preventive measures and detoxification are considered. With regard to modern processing methods for the manufacture of groundnut protein concentrates and isolates, aqueous extraction is briefly described. A milk-like beverage called "Miltone" containing cow's milk and groundnut protein has been developed in India. UNICEF is assisting in scaling-up the production. In the preparation of Miltone wet groundnut protein isolate is used, i.e. spray drying of the isolate is omitted, resulting in a reduction of processing costs.

The ten major cottonseed-producing countries are the U.S.A., the U.S.S.R., China, India, Pakistan, Brazil, Egypt, Turkey, Mexico and the Sudan. Cottonseed protein is not used to any extent for human consumption. Gossypol, the principal pigment of glanded cottonseed (which comprises the bulk of cottonseed used at present) is toxic to monogastric animals (and possibly man). The only commercial process which produces low-gossypol flour from glanded cottonseed is the liquid cyclone process, used by a Texas oil mill. It would appear that so far, edible cottonseed flour has been mainly used in Central America for a food blend called Incaparina, consisting mainly of cottonseed flour, corn (maize) meal and milk powder.

Sunflower and rapeseed protein rank fourth and fifth in world production of oilseed crops. So far as is known, there are no commercial sunflower protein concentrates or isolates available except for some solvent extracted meals. With rapeseed, the problem is that it contains thioglucoside which decomposes yielding undesirable products. A new process producing a bland, non-toxic rapeseed concentrate has been developed in Sweden. Its functional properties are reported to be comparable to those of soybean concentrate.

The world total of protein available from oilseeds in 1972 was estimated by FAO to be 24.3 million tons. As a comparison, world milk production in 1972 provided approximately 15 million tons of protein.

Individual prices for oilseed meals increased significantly between 1971 and 1972 after having been relatively stable between 1965 and 1971. They reached very high levels in mid-1973 and fell again to more normal levels in late 1973 and early 1974. Prices for protein concentrates and isolates depend to a large extent on the scale of production.

Individual prices for vegetable and fish oil showed an upward trend between 1969-71, came to a standstill in mid-1972 and increased again sharply from the end of 1973 to very high levels early in 1974. It is expected that they will decline again in late 1974.

The suitability of oilseed proteins for use in imitation milk depends mainly on their competitiveness as regards functional criteria and cost with milk protein products, in particular with skim milk powder.

A comparison of the essential amino acid pattern of the above oilseed proteins with that of milk protein, shows that the oilseed proteins are deficient in certain essential amino acids and that they possess a lower protein efficiency ratio (PER) and net protein utilization (NPU) than milk protein.

The production of leaf protein concentrate (LPC) for feed and food purposes has been intensively studied over the last 40 years in several parts of the world. Commercial production of feed-grade LPC is underway in the U.S.A. and Hungary. The process employed in the U.S.A. is reported to aim at commercially sound processes to obtain palatable LPC from intermediate or end products of the feed-processing operations.

The production of single cell protein (SCP) for feed and food purposes has also received considerable attention during the last few years by the feed industry, the petroleum industry, industries turning out carbohydrate-containing wastes such as the sugar industry, the brewery industry, the paper and pulp industry, and others. Growing yeasts on carbohydrate-containing media for feed and for food purposes is well known.

The fact that certain microorganisms can grow in hydrocarbons, is the subject of more recent research.

There are two major processes for the manufacture of SCP from hydrocarbons, the gas oil and the normal paraffin process. Both processes have reached the industrial stage in Western Europe and in the U.S.S.R. for the production of yeast powder for animal feed. Japanese manufacturers had to postpone their production plans owing to pressure of public opinion. A process based on methanol as feed stock has also been developed and it has been reported that prices for methanol are likely to rise to a lesser extent than those of normal paraffins.

The PAG has voiced the opinion that, at the present time, SCP grown on purified petroleum fraction can be used safely for animal feeding. With regard to food uses, the PAG has expressed the view that yeasts grown on molasses, sulphite liquors and vegetable wastes have established their safety and nutritional value when employed as a minor component in human diets. PAG further stated that available data suggest that properly selected and produced SCP grown on purified petroleum hydrocarbons will be similarly useful, but appropriate trials will be required before each product is approved for this purpose.

6.2 Conclusions

The attitude of the dairy industry towards milk and milk product imitations may vary from considering such products a challenge to regarding them as a menace. In this context it should not be overlooked that dairy companies are producing "filled" evaporated and condensed milk and that Miltone, the Indian groundnut protein - "toned" milk is produced in a milk plant, hence it is not always easy to draw the line between the manufacturers of milk products and those producing milk product imitations. The author

believes that especially in countries with a highly developed food industry milk will increasingly be used as raw material for this industry, i.e. there will be a rising demand for milk constituents combined with other foods rather than for conventional milk products and milk in its original composition.

The competitive position between the industries manufacturing milk products and their imitations in a given country will also depend to a great extent on the position taken by the government towards protection of milk producers, or, in developing countries, the importance attributed by governments to dairy development.

Generally speaking, the position of governments of many developing countries in establishing development plans is likely to be influenced by the following major tasks: ensuring adequate nutrition of their population, saving foreign exchange and ensuring employment. The latter poses special problems with regard to the rural population because this population normally comprises the greater part of the total population of developing countries. The decision of a government to accord dairy development a certain priority might therefore also be influenced by these considerations - milk being of high nutritional value and dairy husbandry being a labour-intensive branch of agriculture. Governments are also likely to be guided by a desire to improve the socio-economic situation of the rural population. The establishment and expansion of milk collection schemes as an integral part of dairy industry development can play an important role in this respect. Helping to establish and improve the rural communication system through daily contacts between producer, milk plants and collection centres, brings the more remote rural areas closer to industrialized areas, and thus in turn facilitates the spread of information on modern agro-industry development.

Significant price fluctuations during the last decade and in particular the recent considerable increase of world market prices for milk products appear to have induced governments to intensify their efforts to develop local dairy industries.

On the other hand there are a number of factors, in addition to adverse ecological conditions, which could induce governments to import the bulk of the milk products needed, either as final products or as intermediate products for recombination in the country. These reasons may vary from shortage of arable land; to unavailability of loans for dairy husbandry development; to the desire to produce quickly animal protein such as pork and poultry; and to export locally produced oil cake for cattle feeding rather than using it in the country itself, etc.

A government of a developing country which does not allocate priority to dairy development might not be inclined to issue regulations restricting the manufacture and marketing of milk product imitations. This might even be true for governments wanting to support dairy industry development. They may wish to provide low-income groups with less expensive products, using locally produced ingredients in the preparation of imitation milk products, especially vegetable oils for "filled" products; or they may wish to stretch local milk supply by "toning", replacing skim milk powder by vegetable protein, as in the case of Miltone.

Taking into account the projected shortage in 1980 for milk which amounts to more than 15 million tons milk equivalent in developing countries (the balance between effective demand for human consumption and production in these countries), imitation milks could play a very useful role in closing part of the projected gap between demand and production.

Regulations creating more favourable manufacturing and marketing conditions, such as the abandonment of the Filled Milk Act in the U.S.A., and changes of technology and marketing practices are likely to result in an increasing production of imitation milk products. To be successful under commercial conditions imitation milks and imitation milk products

- must be profitable for the producer and the distributor;

- must have intrinsic qualities that will appeal to the consumer (appearance, texture, flavour, etc.) and must be attractively presented (packaging, size, etc.);

- must be backed by an experienced and skilled marketing organization which can promote the product and exploit its appeal to the public.

A number of products have met obviously these requirements, such as coffee whiteners, whipped toppings, filled evaporated and filled condensed milk and certain infant formulae. It would appear that in most cases the use of a vegetable fat less costly than butterfat, with appropriate flavour characteristics, has played a major role in the development of the products.

Replacement of skim milk powder, or more generally speaking of milk protein has proved to be more difficult. Generally speaking the position of milk protein does not seem to be threatened on a short-term basis. The danger which could threaten this position is the widening gap in research development between milk protein and vegetable protein, especially soy protein. Soy protein development has advanced very rapidly, which is to a large extent due to immense research work, and there is some indication that it might replace casein, to an increasing extent, in some imitation milk products owing to its lower price and adequate functional properties.

On the other hand, soy beans are not presently grown in many developing countries. The situation is quite different as regards the two other major oilseeds: groundnuts and cottonseed. Commercial production of edible protein products from these two oilseeds is, however, still low or insignificant. Their theoretically tremendous potential for edible protein products is reduced in practice by the danger of aflatoxin contamination in groundnuts and of gossypol in cottonseed. On a world market level they would have to compete with soy protein products both as regards functionality and price. The use of groundnut protein in imitation milk products may grow, as the example of Miltone shows. The use of cottonseed protein in imitation milk products must also be regarded as a possibility, in particular low-gossypol products obtained by the liquid-cyclone process. Government policies regarding the import of skimmed milk powder and world market prices for the powder will play an important role in regard to the use of these proteins in imitation milk products.

It is difficult to make any definite forecast concerning the use of leaf protein concentrate (LPC) and single cell protein (SCP) in imitation milks for human consumption. The author is of the opinion that SCP will be used as an ingredient in human food in the late 1980s. In the near future SCP and LPC might replace a considerable amount of oilseed meal, fishmeal and skim milk powder for use in specialized animal feeding. The same is likely to be true as regards whey powder. More skim milk powder and oilseed protein could therefore be made available for human food uses, especially if governments of some major dairying countries reduced their subsidies on milk and milk products used as animal feed. As a long-term policy, LPC and also SCP production for animal feed (and later on for food) could be envisaged in developing countries for use in national animal industries and for export.

Finally, it should be stressed that imitations of milk and milk products must be presented to the consumer in a manner which leaves no doubt in the consumer's mind about the type of product he is buying, especially with regard to its nutritional value compared with the milk product imitated.

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Appendix I 1/

CODE OF PRINCIPLES CONCERNING MILK AND MILK PRODUCTS

Application of the Code

Governments are requested to inform the Director-General of FAO or the Director-General of WHO whether they intend to apply the provisions of the Code of Principles as set out below. Governments which so declare their willingness to apply the Code are further requested to state whether they can indicate the date by which they will be able to bring their national requirements into conformity with its provisions, as well as the steps they will require to take in order to achieve this position 2/.

PREAMBLE

The purpose of this Code of Principles is to protect the consumer of milk and milk products and to assist the dairy industry on both the national and international levels by:

ENSURING the precise use of the term "milk" and the terms used for the different milk products;

AVOIDING confusion arising from the mixing of milk and/or milk products with non-milk fats and/or non-milk proteins;

PROHIBITING the use of misleading names and information for products which are not milk or milk products and which might thereby be confused with milk or milk products; and

ESTABLISHING (a) definitions and designations; (b) minimum standards of composition, and (c) standard methods of sampling and analysis for milk and milk products.

Article 1

MILK

1.1 The term "milk" shall mean exclusively the normal mammary secretion obtained from one or more milkings without either addition thereto or extraction therefrom.

1.2 Notwithstanding the provisions of Article 1.1 the term "milk" may be used for milk treated without altering its composition, or for milk the fat content of which has been standardised under domestic legislation.

1.3 The term "milk" may also be used in association with a word or words to designate the type, grade, origin and/or intended use of such milk or to describe the physical treatment or the modification in composition to which it has been subjected, provided that the modification is restricted to an addition and/or withdrawal of natural milk constituents.

1.4 In international trade, the origin of the milk shall be stated if it is not bovine.

1/ Quoted from (52).

2/ See Article 6 of the Code.

Article 2

MILK PRODUCTS

2.1 The terms used to designate milk products shall only be employed for those products which are exclusively derived from milk as defined in Article 1.

2.2 Notwithstanding Article 2.1, the terms used for each milk product may be employed when substances necessary for the manufacturing process are added, provided that these substances are not intended to take the place in part or in whole of any milk constituent.

2.3 The terms used to designate milk products may also be used in association with a word or words to designate the type, grade, origin and/or intended use of such milk products or to describe the physical treatment or the modification in composition to which they have been subjected in accordance with Articles 1.3 and 2.2.

Article 3

COMPOSITE PRODUCTS

3. The term "milk" and the terms used for milk products may also be employed together with a word or words to designate composite products of which no part takes or is intended to take the place of any milk constituent and of which milk or a milk product as referred to in Articles 1 and 2 is an essential part either by quantity or for characterization. If such composite products are designated in terms which are suggestive of milk or milk products or the dairy industry, the label shall indicate the milk or milk product used as well as the other essential constituents.

Article 4

OTHER PRODUCTS

4.1 A product which is neither milk, nor a milk product nor a composite product as referred to in Articles 1, 2 and 3, whatever its origin, source or composition, shall not be described or designated in any label, commercial document or publicity material by words or pictorial devices, or be presented in such manner as to refer to or be suggestive of milk or milk products or other dairy term, if likely to lead the purchaser and/or consumer to suppose that the product is milk, a milk product or a composite product as referred to in Articles 1, 2 and 3.

4.2 Without restricting the scope of Article 4.1, whenever products foreseen by that Article are of such nature as to be likely to lead the purchaser and/or consumer to suppose that they are products as referred to in Articles 1, 2 and 3, the designation of such products shall be presumed to meet the requirements of Article 4.1, if carried out in the following manner:

(a) by the name of the product referred to in Articles 1, 2 and 3 preceded by the word "imitation" in clear type, or

(b) by a distinct name and/or description indicating the true nature of the principal raw materials used.

4.3 In countries where the mixing of milk products with products foreseen by Article 4.1 is not forbidden, wherever the lable of such a mixed product or any publicity referring to it declares the presence of the milk or milk product, the percentage dry matter by weight of the milk ingredients to the total product shall also be indicated, except that where butter is present in a mixture of fats its percentage by weight shall be stated.

Article 5

LABELLING, PRESENTATION AND PUBLICITY

5. No label declarations, methods of presentation and publicity concerning products referred to in Articles 1, 2, 3, 4.2 and 4.3 shall be made in a manner likely to mislead the purchaser and/or consumer as to the true nature of the composition of the product as a whole.

Article 6

EXTENT OF APPLICATION

6.1 Unless otherwise stated, the provisions of this Code shall apply to all products therein considered whether imported, exported or produced and offered for sale upon the home market.

6.2 In view of the relationship between a Federal Government and its constituent States or Provincial Governments, wherever some or all of the provisions of this Code are not regarded as appropriate for Federal action, Federal Governments undertake to make effective arrangements for the reference of such provisions to the appropriate authorities with the request that they give active consideration to the amendment of their State or Provincial requirements in conformity therewith.

6.3 In adapting their practices to this Code, Governments undertake to give earnest and sympathetic consideration as appropriate to the individual standards established in association with the Code according to Resolution No. 16/57 of the FAO Conference.

6.4 This Code and the individual standards established in association with it are not intended to affect the adoption and use of more rigorous requirements or standards under domestic legislation.

Explanatory Notes on the Code of Principles

Note on Article 1 - Milk

1.2 Examples of treatment: clarified, pasteurized or otherwise heat treated. The term "standardized" refers to the standardization of fat content alone, either up or down. However, where specifically so foreseen under national legislation, wholly or partly reconstituted or recombined milk may be considered as standardized within the meaning of Article 1.2 and therefore may likewise be designated as "milk".

Other possible modifications are referred to in the following paragraph.

1.3 Mention of the intended use may accompany the word "milk". The modifications referred to here are only permitted if restricted to an addition and/or withdrawal of natural milk constituents. Modifications shall always be indicated.

Examples:

Type:	Whole and skimmed milk
Origin:	Cow, goat, sheep; alpine
Intended use:	Infant, school (destined for school feeding programmes, etc.)
Treatment:	Sterilized, evaporated, homogenized
Modification:	Humanized, soft curd, vitamin D, or lactose fortified, toned.

Note on Article 2 - Milk Products

2.1 and 2.2 Article 2.1 covers such products as butter, cheese, ghee, cream, dried milk, condensed milk... Examples of substances necessary for the manufacturing process of these products are: for butter - salt, lactic acid culture, colouring matter ...; for cheese - salt, spices, coagulating enzymes of animal and vegetable origin ...; for sweetened condensed milk and ice-cream - sugars ...

2.3 Examples:

Type:	Whole milk powder ...
Origin:	Cow, goat, sheep; alpine
Intended use:	Cooking butter, table butter, coffee cream
Treatment:	Sterilized, evaporated, homogenized ...
Modification:	Humanized, vitaminized ...

Note on Article 3 - Composite Products

Examples:
Flavoured milks, cheese with added foods, milk porridge, milk bread, milk foods with additives, malted milk, milk chocolate, milk candies, sweetened dried milk, ice-cream ...

Note on Article 4 - Other Products

The key provision to the whole Article is contained in 4.1. It lays down that no product which is not a product covered by Articles 1, 2 and 3 may be designated, labelled, advertized or presented in any way which might lead the purchaser or consumer to believe that it was such a product. It is clear, therefore, that such designations as cold cream, vanishing cream, face cream, shaving cream, hair cream and milk of magnesia are perfectly acceptable since no confusion is possible.

Article 4.2 deals with the most important category of products covered by 4.1, those which are of such nature as to be likely to lead the purchaser or consumer to

suppose that they are products covered by Articles 1, 2 and 3, for example, imitation cream or milk containing non-milk fat. For such products, Article 4.2 states that the general requirements of Article 4.1 as to designations will be presumed to have been fulfilled if their designations conform to one or other of the examples given under (a) and (b). It was believed that the use of those designations would be most likely to ensure the protection of the consumer and the producer of milk and milk products. Examples of designations foreseen: under (a) imitation cream; under (b) soya milk, coconut milk, almond milk, peanut butter, skimmed milk with non-milk fat. The true nature of milk or milk products used as foreseen by alternative (b), shall only be described by the term normally used for the milk or milk product in question.

It was further believed in connection with Article 4.2 that the products margarine and vanaspati were correctly designated by the terms "margarine" and "vanaspati" since no confusion could arise by their use. The products would, however, need to be labelled, advertised and presented in a manner which would not confuse the purchaser or consumer in accordance with Article 4.1.

On the other hand, the designations "filled milk", "filled cheese", etc., were held to be misleading within the meaning of Article 4. Their use was, therefore, incompatible with the Code.

Note on Article 5 - Labelling, Presentation and Publicity

This Article is understood to cover the designation of the products referred to.

Note on Article 6 - Extent of Application

As an interim measure it is understood, however, that a country applying the Code would not be restricted by its provisions when exporting to a country which did not apply the Code. It is evident, nevertheless, that the effect of the Code depends largely on the number of countries applying it. Speedy and wide acceptance would therefore hasten the achievement of the objectives at which it aims.

Decisions of the Committee Concerning Certain Declarations of Acceptance

The Committee of Government Experts considered a number of specific points raised by governments in their declarations of acceptance of the Code or of the standards issued thereunder, and decided as follows:

Decision No. 1 -

In respect of the request by the Government of Austria that the designation "Margarinekäse" be accepted under Article 4.2(b), the Committee decided that the designation, being unambiguous and a category designation rather than a trade name, was in complete conformity with that Article.

Decision No. 2 -

In respect of the communication by the Government of New Zealand that under its legislation mixtures of milk products with other types of product (Art. 3 and 4.3) were considered as dairy products whenever the milk product component predominated, the Committee, noting that the Code was concerned with the protection of designations used for the different milk products, decided that such a regulation, provided its intention and effect was to ensure better application of the Code in New Zealand, could be considered compatible with the Code.

Decision No. 3 -

In respect of the communication by the Government of the United Kingdom that the use of the designation "ice-cream" for a product falling under Article 4 of the Code did not create confusion to the United Kingdom consumer the Committee decided that under such circumstances this use of the designation corresponded with the spirit of the Code since it avoided confusion in the mind of the consumer. It was therefore compatible with the Code insofar as the United Kingdom internal market was concerned. The Committee, however, pointed out that this was an exceptional case and that its finding was to be understood in the light of the special position in the United Kingdom which pre-existed the introduction of the Code.

Decision No. 4 -

In respect of the communication by the Government of the United States of America that Article 4.3 did not correspond with its national legislation, in particular in relation to a product described as "filled cheese", the Committee decided that the reservation as to Article 4.3 should be recognized but recommended that the Government of the United States of America give its active attention to the possibility of bringing its federal and state legislation into line with the Code on this point. The Committee further decided that the designation of the product mentioned above did not correspond with the requirements of the Code, but if redesignated in accordance with Article 4.2(b) it could benefit from a Decision similar to No. 1 above.

Decision No. 5 -

The Committee decided that standards adopted under the Code should apply to products so defined, whether made from milk, reconstituted milk or recombined milk or by reconstitution or recombining milk constituents unless the provisions of the standards provide otherwise.

"Reconstituted (product)" is the milk product resulting from the addition of water to the dried or condensed form of (product) in the amount necessary to re-establish the specified water solids ratio.

"Recombined (product)" is the milk product resulting from the combining of milkfat and milk-solids-non-fat in one or more of their various forms with or without water. This combination must be made so as to re-establish the product's specified fat to solids-non-fat ratio and solids to water ratio.

Appendix II

U.S. COMPANIES PRODUCING IMITATION MILK PRODUCTS

FILLED BUTTERMILK (DRY BASES OTHER THAN FAT)

Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.

FILLED CHEESE (DRY BASES OTHER THAN FAT)

Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
Stein Hall & Co., Inc.

FILLED COFFEE CREAM (DRY BASES OTHER THAN FAT)

Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.
Vitax Laboratories

FILLED DIP PRODUCTS (BASES OTHER THAN FAT)

Crest Foods Co., Inc.
Farmer's Daughter, Inc.
General Mills, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

FILLED EGGNOG (DRY BASES OTHER THAN FAT)

Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories

FILLED FROZEN DESSERTS (DRY BASES OTHER THAN FAT)

Zevo, Inc.

FILLED HALF AND HALF (DRY BASES OTHER THAN FAT)

Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.

FILLED MILK (DRY BASES OTHER THAN FAT)

Country Cottage Foods, Inc.
Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Imperial Dairy Foods, Inc.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.

FILLED SOUR CREAM (DRY BASES OTHER THAN FAT)

Crest Foods Co., Inc.
Drew Chemical Corp.
Farmer's Daughter, Inc.
General Mills, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

FILLED WHIPPING CREAM (DRY BASES OTHER THAN FAT)

Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Lever Bros. Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.

FLAVOURED FILLED MILK DRINKS (DRY BASES OTHER THAN FAT)

Dari-Tech Corp.
Farmer's Daughter, Inc.
Germantown Manufacturing Co.
Milk Proteins, Inc.
National Pectin Prod. Co.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION COFFEE CREAM (COMPLETE DRY MIXES)

Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Foremost Foods Co.
Gaymont Laboratories, Inc.
General Mills, Inc.
Milk Proteins, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION COFFEE CREAM (DRY BASE WITHOUT FAT)

Germantown Manufacturing Co.
National Pectin Prod. Co.

IMITATION CREAM CHEESE (COMPLETE DRY MIXES)

Vitex Laboratories

IMITATION FLAVOURED DIPS (COMPLETE DRY MIXES)

Country Cottage Foods, Inc.
Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
Milk Proteins, Inc.
Reddi-Wip, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION FROZEN DESSERTS (COMPLETE DRY MIXES)

Drew Chemical Corp.
Zevo, Inc.

IMITATION HALF AND HALF (COMPLETE DRY MIXES)

Country Cottage Foods, Inc.
Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
Milk Proteins, Inc.
Reddi-Wip, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories

IMITATION HALF AND HALF (DRY BASE WITHOUT FAT)

Germantown Manufacturing Co.
National Pectin Prod. Co.

IMITATION ICE MILK AND ICE CREAM (DRY BASE WITHOUT FAT)

Stein Hall & Co., Inc.

IMITATION MILK (COMPLETE DRY MIXES)

Country Cottage Foods, Inc.
Crest Foods Co., Inc.
Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION MILK (DRY BASE WITHOUT FAT)

Germantown Manufacturing Co.
National Pectin Prod. Co.

IMITATION MILK DRINKS (COMPLETE DRY MIXES)

Archer Daniels Midland Co.
Dari-Tech Corp.
Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
Milk Proteins, Inc.
Reddi-Wip, Inc.
Stein Hall & Co., Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION MILK DRINKS (DRY BASE WITHOUT FAT)

Germantown Manufacturing Co.
National Pectin Prod. Co.

IMITATION SOUR CREAM (COMPLETE DRY MIXES)

Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
General Mills, Inc.
Milk Proteins, Inc.
Reddi-Wip, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

IMITATION WHIPPING CREAM (COMPLETE DRY MIXES)

Dari-Tech Corp.
Drew Chemical Corp.
Farmer's Daughter, Inc.
Gaymont Laboratories, Inc.
Lever Bros. Co.
Milk Proteins, Inc.
Reddi-Wip, Inc.
Stein Hall & Co., Inc.
Unimix, Inc.
Vitex Laboratories
Zevo, Inc.

Appendix III

COMPANIES IN THE U.K. PRODUCING IMITATION MILK PRODUCTS

Dried "filled" milks for human consumption

Manufacturer	Product	Use
Unigate	"Miracle"	Catering and institutions
Pritchet & Co. Hatch End, Middlesex	"Millac" (imported from Ireland)	Catering and vending
Cadbury/Schweppes	"Suprema"	Catering and vending
Rank/Hovis/McDougal	"Melco" (probably produced by UNIGATE)	Catering
Twining & Co.	"Twintops" (May not be filled)	Catering
Brook Bond/Oxo	"Millac" sold under BBO name	Catering
Grimary & Co.	"Glim"	Catering
A.E. Booty	"Somerset"	Catering
Kraft	"Filmilk"	Catering
George Payne & Co.	"Vendalay"	Vending

Non-dairy creamers

Carnation	"Coffee Mate"	
Cadbury/Schweppes	"Complement"	
Glenville	"Coffee King"	
Crode	"Crodamix"	Catering

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